STRATIGRAPHY OF THE LOWER TO LOWER MIDDLE ORDOVICIAN ST. GEORGE GROUP, WESTERN NEWFOUNDLAND

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Cover

Hunters Point, St. John's Bay, provides an excellent exposure of the contact of the Boat Harbour and Catoche formations of the St. George Group. Geological assistant Mike Basha stands on supratidal dolostone at the top of the Boat Harbour Formation, his hand resting on subtidal fossiliferous limestone of the Catoche Formation. Cryptalgal–sponge–metazoan thrombolitic boundstone mounds are accentuated by weathering along the top of the cliff.

GEOLOGICAL SURVEY OF NEWFOUNDLAND
DEPARTMENT OF MINES
GOVERNMENT OF NEWFOUNDLAND AND LABRADOR

STRATIGRAPHY OF THE LOWER TO LOWER MIDDLE ORDOVICIAN ST. GEORGE GROUP, WESTERN NEWFOUNDLAND

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ABSTRACT

The St. George Group is an approximately 500-m-thick sequence of carbonate rock, which accumulated during Early and early Middle Ordovician, in a series of shallow subtidal and peritidal environments near the outer edge of a low latitude continental margin. Lithological variations, in the form of 2 megacycles, reflect deposition in response to eustatic fluctuations in sea level, preceeding and during the early stages of Taconic orogenesis.

Strata are grouped into four formations of roughly equal thickness. The basal **Watts Bight Formation** *is a lower sequence of peritidal limestones and dolostones and an upper thicker, commonly dolomitized succession of burrowed carbonates, distinguished by large digitate thrombolite mounds. The overlying* **Boat Harbour Formation** *is a series of numerous, muddy, peritidal, shallowing-upward sequences of limestone and dolostone. A widespread subaerial disconformity near the top of the formation, reflecting eustatic sea-level fall and the end of the first megacycle, is marked by breccia, quartz–pebble conglomerate, paleokarst and/or extensive dolomitization, and is succeeded by higher energy peritidal limestones called the Barbace Cove Member. The succeeding, thick, monotonous* **Catoche Formation** *is a succession of fossiliferous subtidal limestones with scattered thrombolite mounds whose upper part is locally affected by extensive, multigeneration dolomitization and Pb–Zn mineralization. The St. George Group is capped by the* **Aguathuna Formation,** *a stack of peritidal dolostones and minor limestones and shales deposited during a period of repeated exposure and synsedimentary faulting. An erosional disconformity, resulting from regional compressional tectonics and eustatic sea-level fall, locally marks the top of the St. George Group and the second megacycle.*

INTRODUCTION

Shallow water carbonate rocks of Early Ordovician age are widely disposed over the North American craton and fall into one of two dominant facies. Most belong to an extensive inner cratonic 'dolomite facies' (Harris, 1973; Ross, 1975) deposited in an epeiric sea and dolomitized early in their history. A narrower, outer 'limestone facies', deposited along a continental margin around the outer edge of the early Paleozoic North American plate, is more restricted and now occurs only in mountain belts or buried beneath the modern coastal plain. Rocks of this limestone facies, which outcrop sporadically in the southern and central Appalachians, are buried beneath thrust sheets in the Quebec Appalachians but reappear in the northern Appalachians as an extensive, relatively undeformed outcrop belt along the western coast of Newfoundland.

These rocks in western Newfoundland, which are conspicuously fossiliferous and perhaps better exposed than anywhere else in the Appalachians, have been studied sporadically for over 120 years, but have never been documented in a systematic fashion. The object of this report is to define and explain the stratigraphy of these Lower Ordovician rocks, here called the St. George Group.

REGIONAL GEOLOGY AND GEOGRAPHY

Most of western Newfoundland north of St. George's Bay is composed of late Precambrian crystalline basement and early Paleozoic cover rocks (Figure 1), which together are called the Humber Tectono-stratigraphic Zone (Williams, 1978). This zone is the partially deformed remnant of an originally south-facing (Ross, 1975; Scotese *et al.*, 1979), tropical continental margin (Williams and Stevens, 1974), which bordered the Iapetus (proto-Atlantic) Ocean. Different elements of this margin are now preserved as two contemporaneous, juxtaposed terranes; an autochthon of shallow-water shelf strata tied to basement and two allochthons of deep-water strata and oceanic lithosphere (Rodgers and Neale, 1963). The transported rocks are interpreted to have been obducted during the Taconic Orogeny (Middle Ordovician) and now lie as a series of stacked thrust slices covering a large area around Humber Arm in the south (Humber Arm Allochthon) and a smaller area around Hare Bay in the north (Hare Bay Allochthon). Autochthonous and allochthonous strata were both affected by Acadian (Devonian) deformation. A large block of Precambrian basement was also uplifted and thrust westward during Acadian orogenesis and now forms the core of the Long Range Mountains, the spine of the Great Northern Peninsula.

Lower Paleozoic shallow-water sedimentary rocks, and the Lower Ordovician St. George Group in particular, outcrop in a sinuous belt that skirts around the margins of the allochthons and the Long Range massif, extending a distance of over 400 km from south to north. One of the best studied regions is the southern shore of the Port au Port Peninsula where strata, although broken by Acadian and Carboniferous faulting, are well exposed. Strata to the north around the eastern margin of the Humber Arm Allochthon, are deformed and extensively covered with woodland and thus are known only in a reconnaissance fashion, except for exposures along the margin of two fiords, Goose Arm and Bonne Bay. North of the Humber Arm Allochthon, between Table Point and Cape Norman, strata are well documented because they are almost flat-lying and well exposed in coastal outcrops. The St. George Group also outcrops along the eastern side of the Great Northern Peninsula. In White Bay, strata are vertical. Around the shores and islands of Canada Bay and Hare Bay, the rocks have been mildly to extensively deformed.

HISTORICAL REVIEW

Documentation of these Lower Ordovician rocks has taken place during four distinct periods over the last 100 years (Table 1). The earliest mapping was done in the late 1800's by the Geological Survey of Canada. During the early part of this century, C. Schuchert and C.O. Dunbar, together with students from Yale University, detailed many sections and their results were summarized in 1934 as Geological Society of America Memoir 1. From 1935 to 1965 separate parts of the succession in different areas were studied by several workers, resulting in a new nomenclature for each region. The most recent work, which culminates in this report, has been carried out by the Newfoundland Department of Mines and Memorial University of Newfoundland between 1974 and the present. Stratigraphy of the overlying Table Head Group (Middle Ordovician) has recently been proposed by Klappa *et al.* (1980) and the underlying Middle to Upper Cambrian strata, called the Port au Port Group, by James *et al.*, (1983).

Lithostratigraphy

Geological Survey: In 1861, James Richardson (Logan, 1863) mapped the platformal rocks of western Newfoundland in a reconnaissance fashion. He subdivided the succession and Logan (1863) assigned the rocks to the Potsdam Group (Divisions A-C) and Quebec Group (Divisions D-M). Divisions D to K were defined from sections along the St. Barbe Coast southward to the Port au Choix and Point Riche peninsulas.

Yale Expeditions: These lettered divisions of Richardson (Logan, 1863), formed the framework for the larger synthesis of the whole lower Paleozoic succession by Schuchert and Dunbar (1934). They called divisions D to K the St. George Series and assigned it to the Lower Ordovician and defined strata occurring along the southern shore of the Port au Port Peninsula from March Point to north of 'The Gravels' as the type section.

Local Studies: While mapping Hare Bay near Main Brook, Cooper (1937) recognized two Lower Ordovician limestone units, which he called the Brent Island Limestone and the overlying Southern Arm Limestone. To the south in the Canada Bay area, Betz (1939) placed Lower Ordovician strata in the Chimney Arm Formation, which he separated

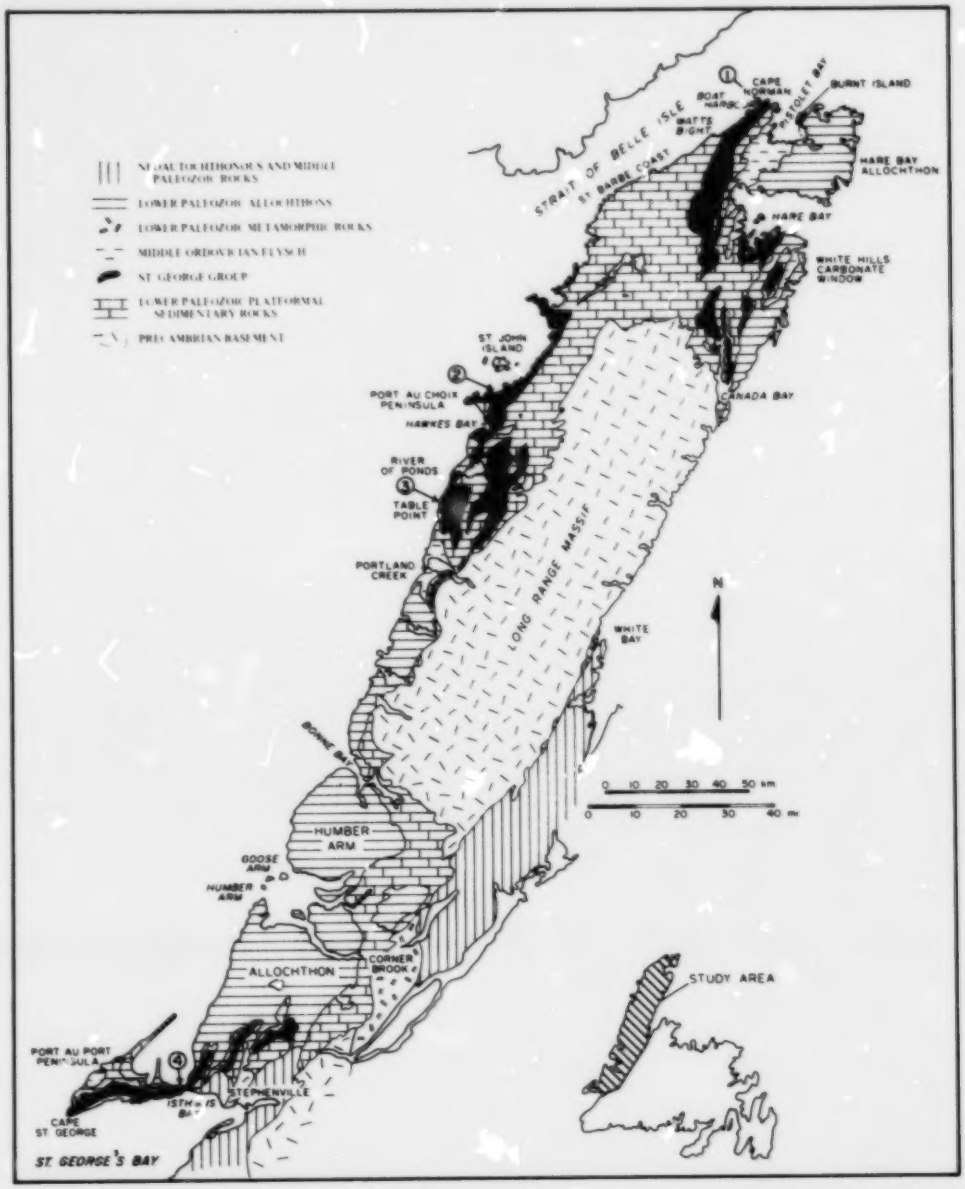


Figure 1. *Geological terranes and outcrop of the St. George Group in western Newfoundland (from Knight and James, 1987). Numbers 1 to 4 show main areas described in the text and illustrated in Figure 3.*

from the Bide Arm Formation, believed to be Middle Ordovician in age. In Humber Arm and Goose Arm, Lilly (1963) and McKillop (1963) divided carbonate rocks into the Hughes Brook and Corner Brook formations and placed them in the St. George Group. The Hughes Brook Formation, consisting of dolostone with some limestone is, however, Cambrian in age. The limestones and dolostones composing the Corner Brook Formation are strongly deformed by thrusts and exposed in recumbent and upright folds (Williams *et al.*, 1982).

Mapping by Sullivan (1940) on the Port au Port Peninsula, Walthier (1949) in the area between Corner Brook and Stephenville, and Nelson (1955) and Woodard (1957) north and south of Port au Choix added to knowledge of the distribution of Lower Ordovician carbonates. Unfortunately, north of Port au Choix many Lower Ordovician limestones were mistakenly placed by Woodard (1957) in the Middle Ordovician Table Head Group.

Recent Investigations: The latest series of investigations, spurred on largely by the discovery of economic mineral deposits and a need to know the stratigraphy for mapping purposes, was begun by Besaw (1974), who mapped the Port au Port Peninsula and divided the St. George Group into five informal units. Kluyver (1975), subdivided Lower Ordovician rocks of the St. George Group in the Port au Choix region, into the Barbace Point, Catoche, and Port au Choix formations. A major zinc deposit occurs in the uppermost part of the St. George Group near Daniel's Harbour. Here the succession was divided informally by Collins and Smith (1975) into three units; namely, Lower limestone, the middle Dark gray dolomite, and the upper Cyclic dolomite, which they concluded lay beneath a disconformity at the base of the Table Head Group. They suggested that beneath this disconformity a major karst system developed within the St. George Group in the late Early Ordovician and played an important role in ore genesis.

The first attempt at integration was undertaken by Levesque (1977), who, in a M.Sc. study, produced the first synthesis of the Cambrian–Ordovician sedimentary rocks in western Newfoundland since Schuchert and Dunbar (1934). Realizing that the study was preliminary, Levesque (1977) retained existing nomenclature, referring the rocks to the St. George Formation and subdividing them into a lower cyclic member, a middle limestone member and an upper cyclic member.

Simultaneously, Knight (1977, 1978) began a long-term study of strata from Table Point to Cape Norman and proposed several informal units. At first he placed five rock units in the St. George Group (Knight, 1977) and named them the Unfortunate Cove, Watts Bight, Catoche, Diagenetic carbonates, and Silicious dolomite formations. Subsequent mapping indicated that the Unfortunate Cove is probably Late Cambrian in age and it was subsequently withdrawn from the St. George Group and placed in the Port au Port Group (Knight, 1978, 1980b). Limestones previously included within the Catoche Formation were separated into the Boat Harbour Formation and an overlying unit that continued to be called the Catoche Formation (Knight, 1978, 1980b). The 'diagenetic carbonates', understood to be a diagenetic facies, were assigned to the upper part of the Catoche Formation (Knight, 1980b). The Siliceous dolomite formation was informally referred to as the Bellburns formation. These units have proven to be consistent and mappable over large areas (Knight *et al.*, 1983a,b; Knight and Edwards, 1978a,b; Knight and Snow, 1978; Knight *et al.*, 1979, 1980; Stouge, 1983a,b).

During the same period, researchers from Memorial University concentrated on specific aspects of the St. George Group. Stevens and James (1976) reported a series of sponge–algal mounds that occupy part of the Catoche Formation in Hare Bay. An M.Sc. dissertation by Pratt (1979) focussed on the sedimentology of the St. George Group and led to reports on cryptalgal mounds (Pratt and James, 1982), cryptalgal fabrics in general (Pratt, 1982a, b) and a model for deposition of the St. George Group (Pratt and James, 1986). In their papers, Pratt and James informally named the three units of Levesque, the Isthmus Bay (Lower Cyclic Member), Catoche (Middle Limestone) and Aguathuna (Upper Cyclic Member) formations. There now appears to be enough difference between the units that comprise the Isthmus Bay Formation to break it into two formations, which correspond to the Watts Bight, and Boat Harbour units of the Great Northern Peninsula.

Paleontology and Biostratigraphy

Much of the stratigraphic confusion has come about because of poor biostratigraphic control. Fossil collecting during the early years was not pursued in any systematic fashion. Samples taken by Richardson were monographed by Billings (1865) and subsequent documentation was usually in the form of fossil lists reported together with stratigraphic sections (Schuchert and Dunbar, 1934). Johnson (1949) provided both lithological and fossil descriptions but the study was not published. Because of the large scale of the area, reconnaissance nature of the mapping and lithological similarity, units were defined on fossil content rather than on lithology.

Biostratigraphy of the St. George Group, directed at either determining the age of units or the nature of the specific faunas, was begun in the 1960's by Whittington and Kindle (1969). They detailed trilobites in the Port au Port sections and showed that much of the St. George Group as defined by Schuchert and Dunbar (1934) was Cambrian in age. Since then, the nature of various faunas has been documented by different workers; trilobites (Fortey, 1979; Boyce, 1979, 1983a,b; 1985), cephalopods (Flower, 1978), conodonts (Tuke, 1968; Barnes and Tuke, 1970; Stouge, 1982) and graptolites (Cumming, 1967; Williams *et al.*, 1987).

AGE

The St. George Group is mostly Canadian (Ibexian of Ross *et al.*, 1982) in age. The precise age of the base is uncertain because the dolostones have yielded few diagnostic fossils. The age of the top is poorly known for the same reason and because it was locally eroded prior to deposition of the Middle Ordovician Table Head Group, it may also vary from place to place.

The stratigraphic sequence appears to be continuous except for two breaks. The lowest occurs near the top of the Boat Harbour Formation and a hiatus is suggested at this level by the absence of trilobites equivalent to Ross–Hintze fauna G_1 of the western USA (Boyce, 1983b). The other, near the top of the St. George Group lies within or at the top of the Aguathuna Formation (Cumming, 1968; James *et al.*, 1980; Pratt and James, 1982; Stouge, 1982; Knight, 1983, 1985a, 1986).

STRATIGRAPHIC NOMENCLATURE AND PROBLEMS

Definition and description follows the general format outlined under Definition of Formal Units–Article 3 of the recent, North American Stratigraphic Code published by the

Table 1. *Stratigraphic nomenclature used for known and postulated lower Ordovician authochthonous rocks in western Newfoundland; rock units of different authors are matched approximately.*

AUTHOR	LOGAN		SCHUCHERT & DUNBAR		COOPER; STOUGE	BETZ	TROELSEN; WALTHIER; TWENHOFEL ET AL.	LILLY; MCKILLOP		WHITTINGTON & KINDLE; SMIT; SWETT & SMIT	BESAW	
YEAR	1863		1934		1937 1963b	1939	1947; 1949; 1954	1963; 1963		1969; 1971; 1972	1974	
AREA	W. NFLD.		W. NFLD.		HARE BAY	CANADA BAY	BONNE BAY; CORNER B.X. – STEPHENVILLE; W. NFLD.	GOOSE ARM; HUMBER ARM		W. NFLD.	PORT AU PORT PENINSULA	
OVERLYING UNIT	QUEBEC GROUP	KTON	ORDOVICIAN	TABLE HEAD SERIES	HARE ISLAND LST.	BIDE ARM FM.		TABLE HEAD GROUP		TABLE HEAD FM.	TABLE HEAD GROUP	
LOWER ORDOVICIAN NOMENCLATURE	QUEBEC GROUP	IHGFED	ORDOVICIAN	ST. GEORGE SERIES	SOUTHERN ARM LST.	CHIMNEY ARM FM.	ST. GEORGE GROUP	ST. GEORGE GROUP	CORNER BROOK FM.	ST. GEORGE FORMATION	ST. GEORGE GP.	PORT AU PORT UNIT
					BRENT ISLAND LST.				HUGHES BROOK FM.			WHITE HILLS UNIT
												PIPE TREE UNIT
												PIGEON HEAD UNIT
			CAMBRIAN	MARCH POINT SERIES & LABRADOR SERIES						PETIT JAROIN & MARCH POINT FMS.		LOWER COVE UNIT
UNDERLYING UNIT	POTSDAM GROUP A TOC		CAMBRIAN			TREYTOWN POND FM.		RELUCTANT HEAD & PENGUIN COVE FMS.				

Table 1. *(Continued)*

	KLUYVER	COLLINS & SMITH	LEVESQUE	KNIGHT	KNIGHT	PRATT; PRATT & JAMES; JAMES ET AL.; JAMES & STEVENS	KNIGHT & JAMES
	1975	1975	1977	1977	1978 1980b	1979; 1982; 1980; 1982	THIS STUDY
	PORT AU CHOIX	DANIELS HARBOUR	PORT AU PORT TO PORT AU CHOIX	NORTHERN PENINSULA	NORTHERN PENINSULA	W. NFLD.	W. NFLD.
	TABLE HEAD GROUP	TABLE HEAD GROUP		TABLE HEAD FM	TABLE HEAD GROUP	TABLE HEAD GROUP	TABLE HEAD GROUP
	PORT AU CHOIX FM.	CYCLIC DOLOMITES	ST. GEORGE FORMATION: UPPER CYCLIC MEMBER	ST. GEORGE GROUP: SILICEOUS DOLOMITE FM	ST. GEORGE GP: BELLBURNS FM	ST. GEORGE GP: AGUATHUNA FM.	ST. GEORGE GP: AGUATHUNA FM
		DARK GRAY DOLOMITE		DIAGENETIC CARBONATE	CATOCHE FM	CATOCHE FM	CATOCHE FM
	CATOCHE FM.	LOWER LIMESTONE	MIDDLE LIMESTONE MBR	CATOCHE FM	BOAT HARBOUR FM	ISTHMUS BAY FM	BOAT HARBOUR FM
	BARBACE POINT FM.	?	LOWER CYCLIC MEMBER	WATTS BIGHT FM UNFORTUNATE COVE FM	WATTS BIGHT FM		WATTS BIGHT FM
			PETIT JARDIN & MARCH POINT FMS	DOLOMITE & MICRITE FM	PETIT JARDIN & MARCH POINT FMS	PETIT JARDIN & MARCH POINT FMS	PORT AU PORT GROUP

American Association of Petroleum Geologists (1983). Designation of unit stratotype, boundary stratotypes, type locality, reference sections (where necessary) and stratotype descriptions are all applied to the rock units as outlined in Article 8 of the same code. Unit descriptions, boundaries, historical background, dimensions, shape and other regional aspects (i.e., variations), geological age, correlations and possibly genesis (i.e., Articles 9 to 15) are then listed to provide a comprehensive and ordered picture of the different lithostratigraphic units. Detailed logged sections of formation stratotypes and reference sections are given in the appendix.

DOLOMITIZATION

A major problem in lithostratigraphic definition is presented by variable dolomitization. Similiarity in dolostones now known to be of different ages has in the past led to confusion in mapping. Strata that are irregularly dolomitized equivalents of true limestone units have also been called formations (e.g., Port au Choix Formation of Kluyver, 1975). In this report, we utilize a variation of the scheme presented by Friedman and Sanders (1967) and recognize three different dolostones called syngenetic, diagenetic and epigenetic. Whereas syngenetic dolostone is an integral part of the lithostratigraphy, diagenetic and epigenetic dolostone, characterized by cross-cutting relationships, pervasive dolomitization that may or may not obliterate original textures, increased porosity and the development of later dolomite cements, create acute problems when defining lithostratigraphy.

Syngenetic dolostone is very finely crystalline, equigranular, idiotopic dolomite. It is typically laminated, interbedded with limestone or shale and preserves original sedimentary structures.

Diagenetic dolostone may be fabric-specific, replacing specific constituents (e.g., gastropods) or structures (e.g., burrows) or it may be pervasive. The pervasive dolostone may be stratabound or cross-cutting, but generally preserves some rock textures and fabric.

Pervasive diagenetic dolostone is typically tan to grey weathering; micro to medium crystalline, hypidiotopic to xenotopic, dark grey to light grey dolomite. It occupies consistent stratigraphic positions in the succession and has been mapped throughout much of western Newfoundland. The dolostone preserves original bedding and sedimentary textures. It replaces a substantial part of the upper 50 m of the Catoche Formation and much of the Watts Bight Formation in the northern part of the area. There is, however, sufficient original individuality preserved to allow the consistent identification and delineation of distinct formations or members.

Epigenetic dolostone is very fine to more commonly coarsely-crystalline or sucrosic, inequigranular, xenotopic to hypidiotopic, vuggy, grey to tan-grey dolomite. Depositional texture can be poorly preserved or obliterated and major dissolution in many instances has enhanced open spaces between irregular domains of dark dolomite. These spaces were later lined or closed by very coarsely crystalline white sparry dolomite. The resulting rock in western Newfoundland has been called 'pseudobreccia' by Cumming (1968), Collins and Smith (1975) and Lane (1984), and is host to zinc mineralization on the Great Northern Peninsula. Epigenetic dolostones can be readily distinguished where they cross-cut bedding, are laterally variable over short distances and are clearly related to faults, joints and gentle folds.

PROPOSED STRATIGRAPHY

Rocks loosely called the St. George Series, St. George Formation, or St. George Group have in the past included a wide group of lithologies, generally encompassing all carbonates below the distinctive Table Head Group and above the terrigeneous clastic strata of the Labrador Group. Both Levesque (1977) and Knight (1977), recognized that Ordovician rocks generally called the St. George were lithologically distinctive from the less fossiliferous, more siliciclastic and often higher energy Cambrian carbonates, which underlie them.

Here, we propose that the lithologically different Cambrian rocks be excluded and that the section of limestone and dolostone, which are mostly Lower Ordovician in age, be formally brought together under the rank of group, called by the name St. George Group. Within this group we propose formally to newly define three formations, the Watts Bight, Boat Harbour and Aguathuna formations. A fourth unit, the Catoche Formation, originally proposed by Kluyver (1975), is retained but redefined.

Kluyver (1975) is the only investigator to formally propose names for units within the St. George Group. His studies centred only on the Port au Choix, and Pointe Riche peninsulas near Port au Choix, which contain an incompletely exposed and a somewhat atypical section of the upper half of the St. George Group. He proposed three formations (see Table 1), and we have retained the name Catoche Formation, which he used for a middle limestone unit straddled by two formations composed mostly of dolostones. We revise the boundaries and the extent of this formation so that it includes most of Kluyver's Port au Choix Formation, which we propose be abandoned. As he defined the Port au Choix Formation, it underlies directly Middle Ordovician limestones of the Table Head Group, and is composed of diagenetic dolostone that replaces limestone in the upper 40 m of our Catoche Formation. These dolostones possess original sedimentary fabrics, e.g., bedding structures, bioturbation and fossil ghosts, and also rafts of limestone, indicating that they are replaced limestones. His Port au Choix Formation, however, also includes a few metres of syngenetic dolostone that belongs to the new Aguathuna Formation. For these reasons, we suggest the formation be abandoned.

Below the Catoche Formation, Kluyver (1975) proposed the Barbace Point Formation for a section of limestone and

epigenetic dolostone that occurs on the northern part of the Port au Choix Peninsula. However, the section covers only the topmost 50 m of the new Boat Harbour Formation that is 120- to 150-m thick elsewhere in western Newfoundland. The strong overprint of mostly epigenetic dolostone, together with this incomplete section, has led us to include this unit in the more readily mappable Boat Harbour Formation.

ST. GEORGE GROUP

The St. George Group is a succession of limestone, dolomitic limestone, dolostone and minor calcareous and dolomitic shale of subtidal to peritidal aspect. Well-bedded, bioturbated, fossiliferous, mudstone to packstone with grainstone lenses or layers and cryptalgal boundstone mounds characterize thick sections of subtidal aspect. Similar lithologies plus a variety of muddy and grainy carbonates arranged in repetitive sequences (shallowing-upward sequences of James, 1984) characterize other sections of peritidal character. Other lithologies include parted, flaser-bedded, sparsely bioturbated, and fossiliferous lime and dolomite mudstone to packstone with ripple-marked, skeletal, intraclastic and rarely oolitic grainstone, and mud-cracked, laminated, dolomitic lime mudstone, dolostone or dolomitic shale. Horizons believed to record episodes of local and regional subaerial exposure within these cyclic carbonates are characterized by sedimentary breccias, quartz-pebble and sand lags and irregular solution surfaces. Viewed on a large scale, the sequence comprises four rock units that reflect accretion of the Lower Ordovician continental shelf by an alternating succession of subtidal–peritidal–subtidal–peritidal carbonate sediments. This four-fold arrangement consists in ascending order of the Watts Bight, Boat Harbour, Catoche and Aguathuna formations (Figure 2).

The base of the St. George Group is defined where thick bedded limestones or diagenetic dolostones conformably overlie rocks of the Port au Port Group. On the Port au Port Peninsula, in Goose Arm and possibly in Canada Bay, the dark-coloured limestones and diagenetic dolostones of the St. George Group, dominated by cryptalgal boundstones and bioturbation, overlie intercalated pale grey limestones, and yellow-weathering syngenetic dolostones and shales of probable Late Cambrian age. These rocks are transitional in composition between typical Cambrian and Ordovician rocks; we have assigned them to the underlying Port au Port Group (James *et al.*, 1983). On the Great Northern Peninsula, tan grey to black diagenetic dolostones, again composed of cryptalgal mounds and bioturbated carbonate, rest upon thick-bedded, yellow-, buff- to white-weathering, pale grey to grey, syngenetic dolostones of the Port au Port Group (Knight, 1977, 1978, 1980b).

The top of the St. George Group is defined at the contact with the overlying Table Head Group. On the Port au Port Peninsula, this contact is a well-known erosional disconformity, where cyclic dolostones, shales and limestones at the top of the St. George Group are truncated over several metres and overlain by well-bedded limestones of the Table Head Group. On the Great Northern Peninsula, the contact between overlying limestones and underlying dolostones appears to be conformable (Knight, 1977, 1978; Fortey, 1979; Stouge, 1982; Lane, 1984) to locally disconformable (Cumming, 1983; Knight, 1986, 1987). The contact is placed at the top of the uppermost dolostone of the Aguathuna Formation.

Schuchert and Dunbar (1934) first applied the name St. George Series to Lower Ordovician carbonate rocks of the southern shore of the Port au Port Peninsula and extended the name to include Lower Ordovician carbonate rocks on the Great Northern Peninsula. The series was later termed the St. George Formation by Twenhofel *et al.* (1954), Kindle and Whittington (1965), Whittington and Kindle (1969), and Levesque (1977), and St. George Group by Johnson (1949), Nelson (1955), Woodard (1957), Knight (1977, 1978, 1980b), James *et al.* (1980) and Pratt and James (1982).

Watts Bight Formation

Formation stratotype: The shoreline from 2.4 km south of Open Bay, and along the west and north shore of Boat Head (Figure 3a) (N.T.S. 12P/9 Grid Reference 56649 571300 to N.T.S. 2M/12 Grid Reference 57035 571665). The section outcrops as a succession of low cliffs and rocky shoreline. Access to the south side of Open Bay is easiest by small boat.

Type locality: The formation is named after Watts Bight, the small drowned estuary of Open Bay, 2 km south of the village of North Boat Harbour (N.T.S. 12P/9, Big Brook).

Reference section: Western shore of Isthmus Bay (Figure 3d) from 1.4 km southwest of the gravel bar and continuing northward along the shore for 0.5 km (N.T.S. 12B/10, Grid Reference 371800 5377800 to 372000 5378500).

Lithological character: The rocks are muddy, bioturbated carbonates of generally subtidal and local peritidal aspect, characterized by the presence of relatively large and complex thrombolite mounds (Figure 4). Sediments vary from dolostone at the type area along the St. Barbe coast to selectively dolomitized limestone at the reference section on the eastern Port au Port Peninsula to almost entirely limestone at Canada and Hare bays and the western Port au Port Peninsula.

The lower part of the formation contains numerous thrombolitic and stromatolitic boundstone units that commonly display a cerebral weathering pattern (Plate 1a). These thick-bedded carbonates include sequences of mottled, thin-bedded, dark grey dolostone (Plate 1b) and thick beds of large mounds that are capped by laminated dolostone or lime mudstone or cryptalgal laminite (Plate 1c). Red and black chert layers and nodules replace the carbonates and cap many of the mound beds. The top of this lower succession of mounds at Isthmus Bay consists of a prominent cryptalgal mound complex at Green Head that is described in detail by Pratt and James (1982). Mounds decline in number stratigraphically upward on the Great Northern Peninsula, and become isolated within bioturbated dolostones.

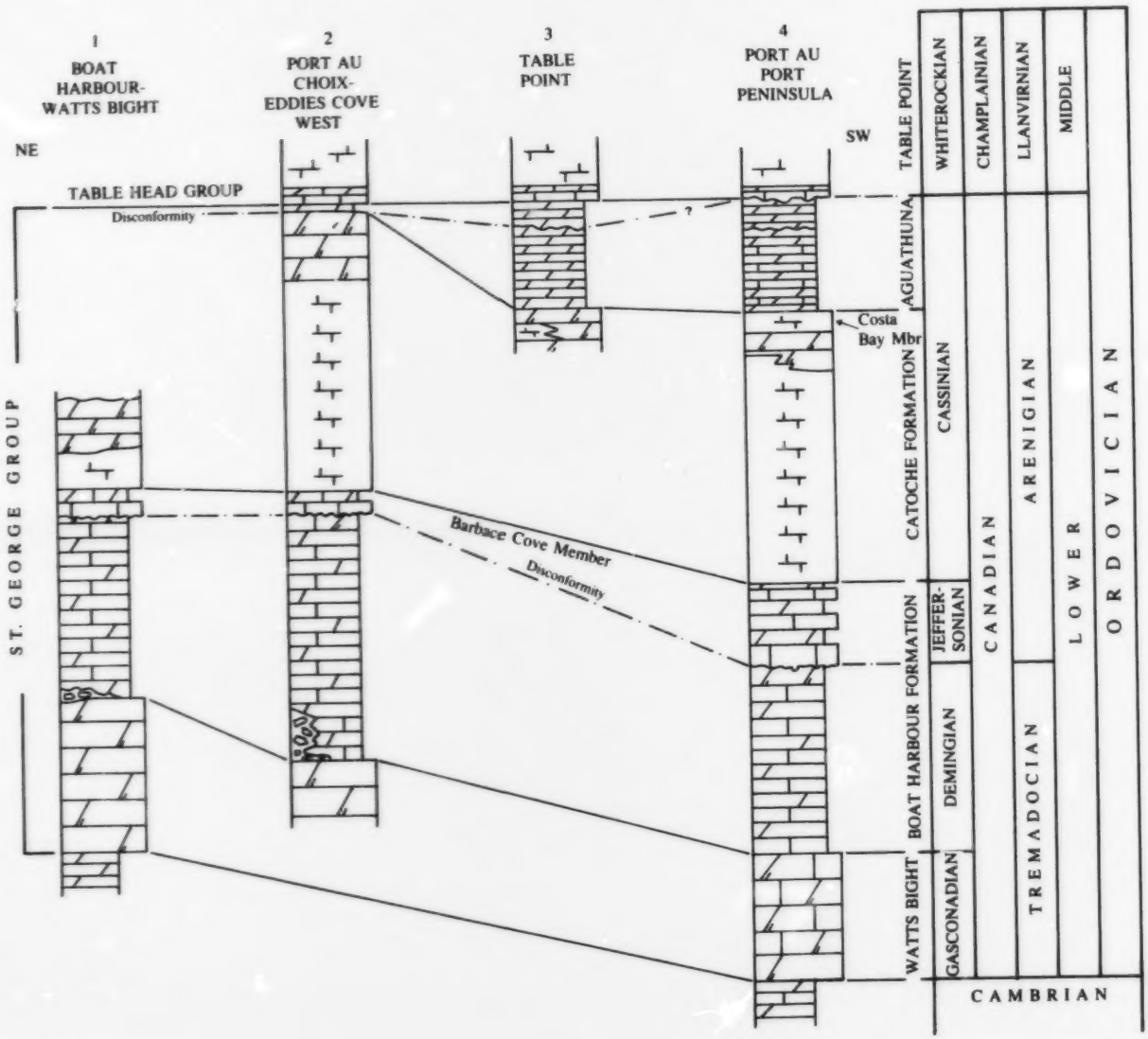


Figure 2. *Stratigraphic subdivisions described in the text (from Knight and James, 1987);* ⊥⊤ *–limestone,* ⊥⊤ *–dolostone,* ⊥⊤ *–secondary dolostone;* solid lines, *formational and group contacts;* dashed–dotted line, *disconformity;* *breccia.*

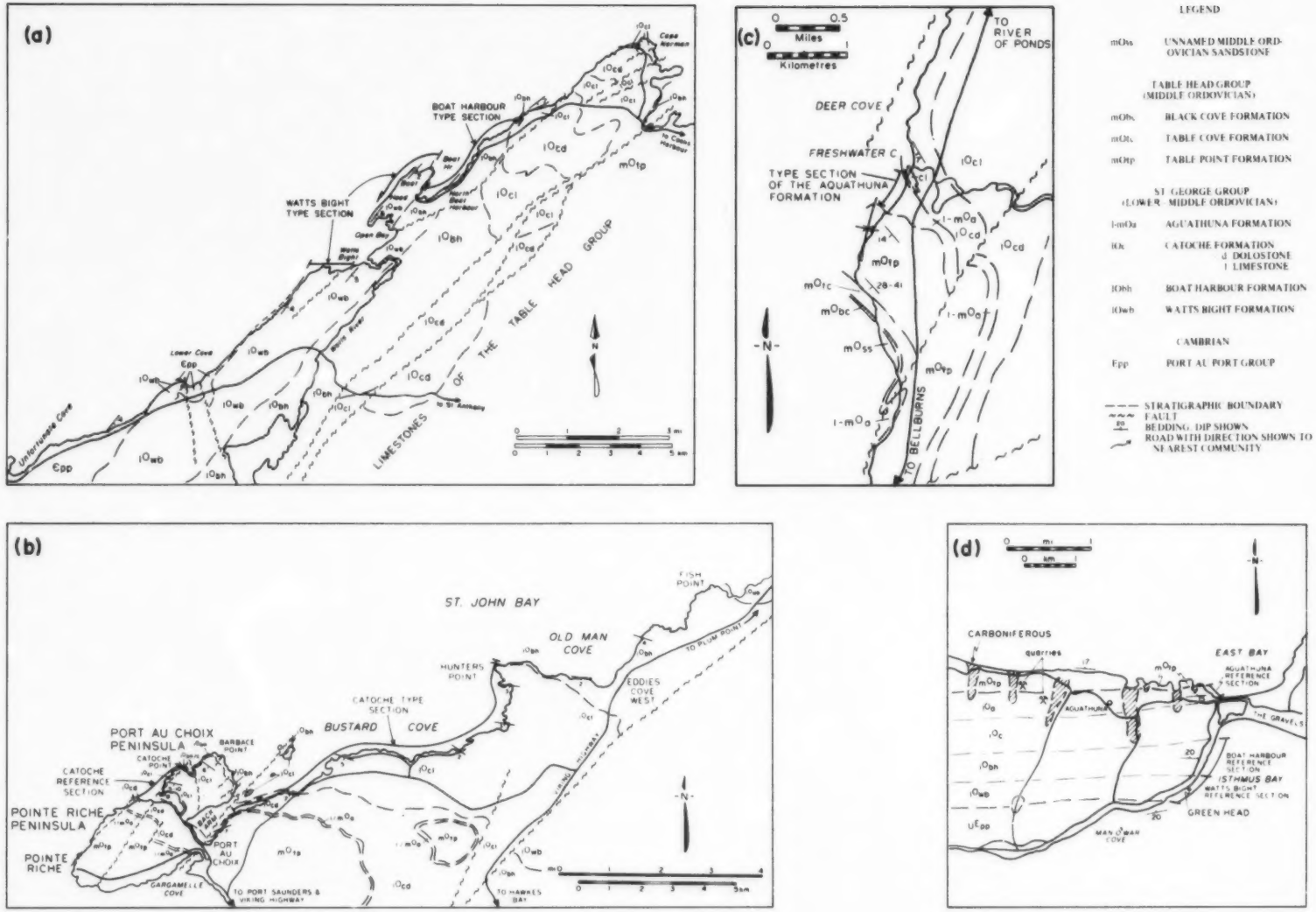


Figure 3. *Detailed geology and location of sections in areas 1 to 4 of Figure 1 (from Knight and James, 1987); (a) geological map of the Watts Bight and Boat Harbour Area (area 1, Figure 1); (modified from Knight and Edwards, 1978a, b); (b) geological map of the Port au Choix Area (area 2, Figure 1) (modified from Knight et al., 1983a, b); (c) geological map of the Table Point Area (area 3, Figure 1) (from Knight, 1985b); (d) geological map of the eastern part of the Port au Port Peninsula (area 4, Figure 1) (James, unpublished data).*

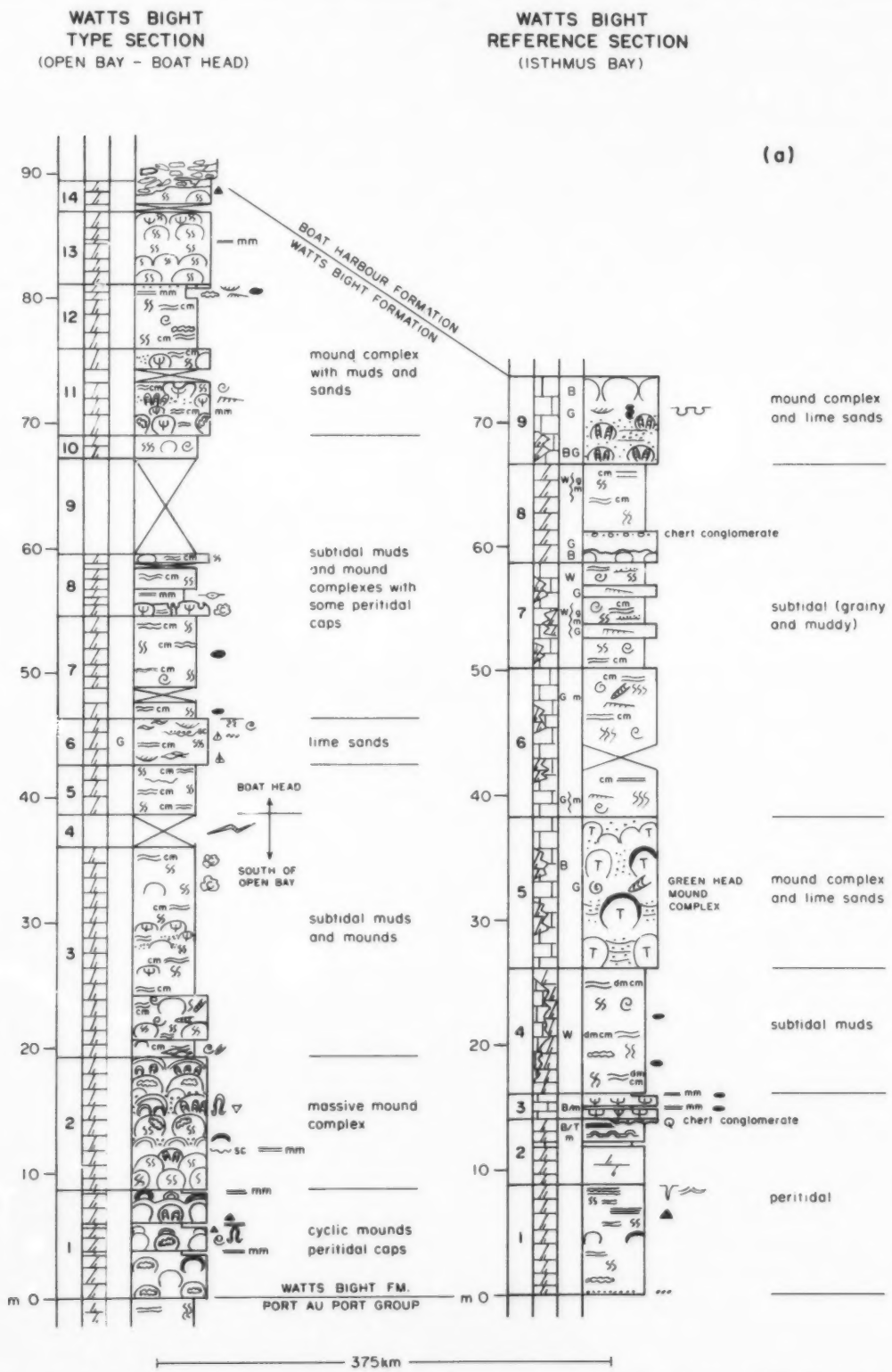
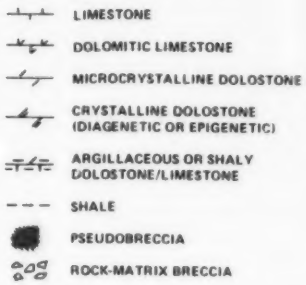


Figure 4. *(a) Type and reference sections of the Watts Bight Formation (from Knight and James, 1987); legend is also common for Figures 5, 6 and 7.*

LEGEND FOR GRAPHIC SECTIONS

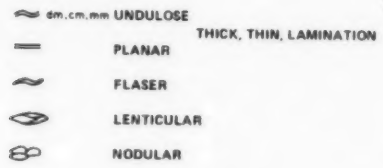
ROCK TYPES



TEXTURAL CLASS

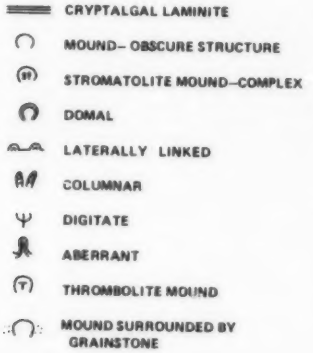
M	MUDSTONE
W	WACKESTONE
P	PACKSTONE
G	GRAINSTONE
R	RUDSTONE
B	BOUNDSTONE
G/M	INTERCALATED TEXTURAL CLASSES

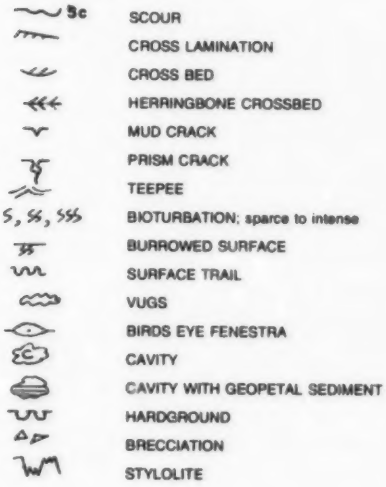
BEDDING WITHIN UNITS



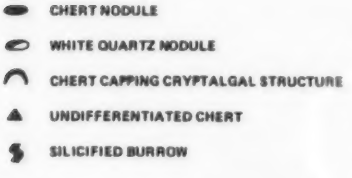
GRAINS

CRYPTALGAL STRUCTURES





SILICIFICATION



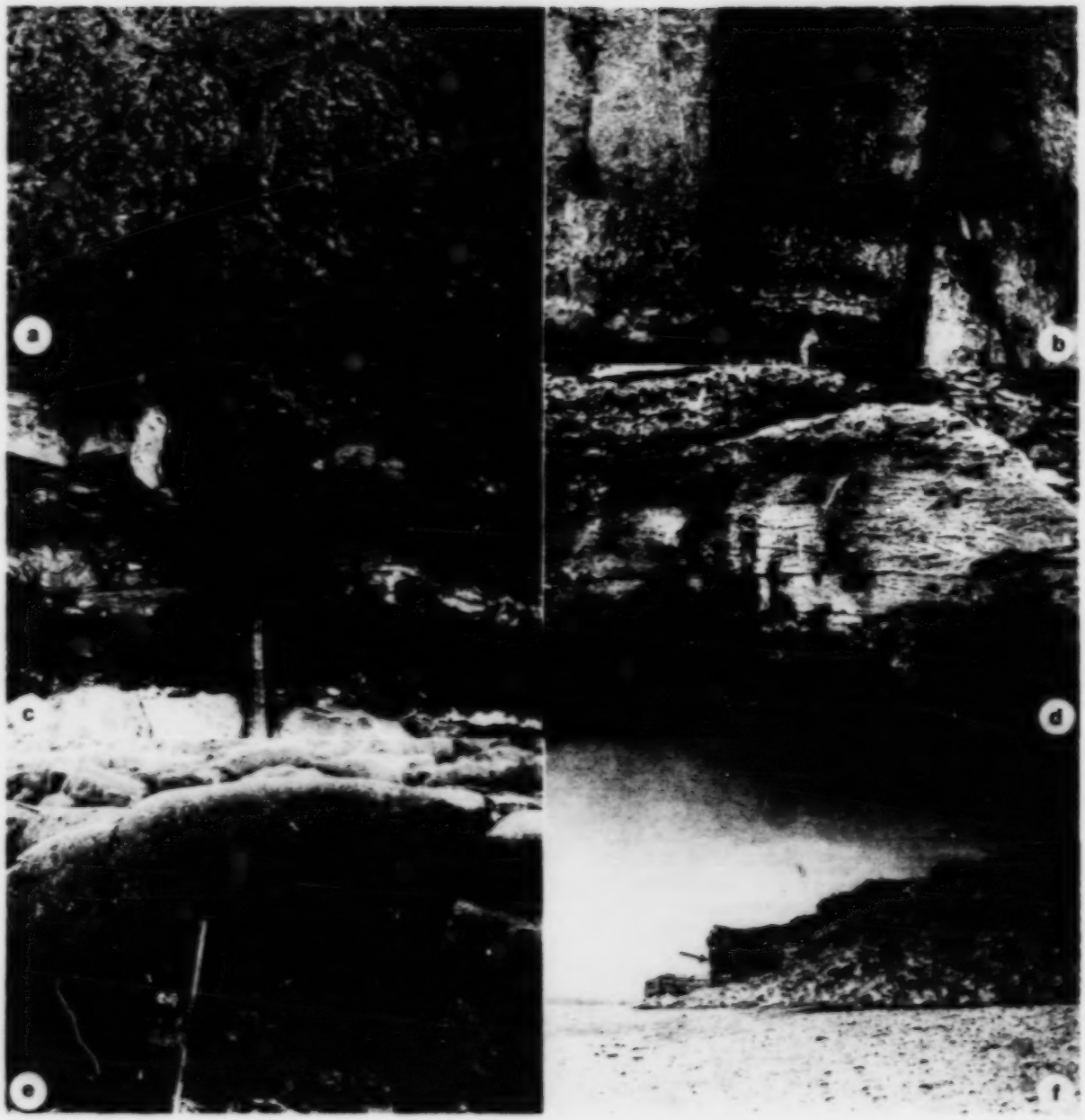


Plate 1. *Typical sedimentary features of the Watts Bight Formation;* (a) *thrombolite mounds showing cerebral mottled pattern in dolostone, north of Fish Point, St. John Bay;* (b) *burrow mottling in thick dolostone bed, Lower Cove;* (c) *thin dololaminite lying between thick beds of thrombolitic dolostone. Partly silicified (white areas) stromatolites occur at the base of the overlying bed; Watts Bight type section;* (d) *cross-bedded dolostone overlying stromatolites, Castor Point Peninsula;* (e) *large mounds above domolaminite, upper mound sequence, Boat Head;* (f) *basal contact of the Watts Bight Formation (arrow) with Cambrian dolostones, southwest of Lower Cove (from Knight and James, 1987).*

The middle part of the formation is a sequence of bioturbated carbonate, dolomitized in the north but varies from lime mudstone to massive grainstone, to thick beds of cross-bedded grainstone in the south. The top of the formation is distinguished by thrombolitic and stromatolitic boundstone mound beds associated with grainstone at Isthmus Bay and some bioturbated dolostone and dolarenite at Boat Head and elsewhere on the Great Northern Peninsula (Plates 1d and e). Laminated and cross-laminated microcrystalline dolostone cap boundstone and mottled dolomite packages in the type section, whereas hardgrounds and local brecciation occur in limestone at the top of the Isthmus Bay section.

Thickness: Approximately 89 m at the type section; 73 m at the reference section.

Lower boundary: A conformable contact. In the type area, the boundary is placed at the base of thick beds of dark grey to black, cherty, vuggy crystalline dolostone that overlies a 4.2-m-thick unit of thinly bedded, bioturbated, finely crystalline, grey dolostone. At the first lower boundary reference locality (roadstone quarry), the unit is 6.25-m thick and is intercalated with layers of wavy laminated, lenticular-bedded dolostone and cryptalgal laminite. The bioturbated dolostone overlies a poorly exposed succession of buff- to yellow-weathering, light grey to dark grey, finely crystalline, Cambrian dolostones that exhibit mud-cracks, stromatolites and some bioturbation.

Lower boundary stratotype. Southwest side of Lower Cove (Plate 1f), (Big Brook map sheet, N.T.S. 12P/9, Grid Reference 56355 571055).

Lower boundary reference localities. 1) Roadstone quarry on the west side of route 63, (Viking Highway), 10.5 km south of the junction with route 432 to Main Brook and Roddickton. (Castor River map sheet, N.T.S. 12I/15; Grid Reference 50735 564780; 2) Southwest point on west side of Isthmus Bay (Stephenville map sheet, N.T.S. 12B/10, Grid Reference 371800 5377800).

Upper boundary: Probably conformable as seen locally at Fish Point, Castors Peninsula and on the Port au Port Peninsula. The relationship is obscured at the type locality and over large areas of the Northern Peninsula, by an extensively developed series of light grey, dolostone–chert breccias that rest upon dark grey, Watts Bight dolomite. On the Port au Port Peninsula, the contact is conformable with mounded and bioturbated limestones and dolostones passing abruptly to cyclic peritidal limestones that are locally replaced by pale grey dolostone.

Upper boundary stratotype: north of Green Head, west side of Isthmus Bay, 0.9 km south of gravel bar (Stephenville map sheet, N.T.S. 12B/10, Grid Reference 372000 5378500).

Upper boundary reference localities: 1) northwest point of Round Head Island, St. John Bay (St. John Island map sheet, N.T.S. 12I/14, Grid Reference 48725 562875); 2) small cove 0.9 km east of Fish Point, St. John Bay (St. John Island map sheet, N.T.S. 12I/14, Grid Reference 49175 562475).

Historical background: The dolostones of the formation are probably part of division E of Richardson (Logan, 1863) although the description of this division by Schuchert and Dunbar (1934) gives no hint that they recognized it individually. The unit was first separated, described and named informally as the Watts Bight Formation by Knight (1977) in the area of Boat Harbour. Subsequent mapping showed the formation to be extensively developed and lithologically consistent on the Northern Peninsula (Knight, 1978, 1979, 1980a; Knight *et al.*, 1983a,b). On the Port au Port Peninsula, Levesque (1977) first recognized that these rocks were distinctively different from the underlying higher energy Upper Cambrian beds and included them in his Lower Ordovician 'Lower Cyclic Member' of the St. George Group. Later these rocks were included in the Isthmus Bay formation by James *et al.* (1980), and Pratt and James (1982, 1986).

Regional relationships: In autochthonous and parautochthonous strata in Canada Bay, the formation is composed of black limestones with cherty dolostones only preserved in the lower 6 to 17 m (Knight and Saltman, 1980). The limestones preserve large thrombolite mounds and bedded, dolomite burrow-mottled limestones. Peritidal dolostones are absent.

Characteristic fossils: Ellesmeroceratid cephalopods, plani- and high-spired gastropods, trilobites and conodonts (Flower, 1978; Stouge, 1982).

Age: Cephalopods and gastropods recovered by Flower (1978) from Isthmus Bay persuaded him that these rocks were Early Canadian, belonging to the Gasconadian Stage. Conodonts from the upper part of the formation in Canada Bay (Stouge, 1982) include elements of Midcontinent Fauna B and C of Ethington and Clark (1971) supporting an Early Canadian age. Conodonts from the basal and middle part on the western Port au Port Peninsula are of similar age; conodonts from the upper part indicate a Fauna D age (close to the Tremadoc–Arenig boundary) (C.R. Barnes, personal communication, 1986).

Depositional environment: A generally subtidal open shelf environment containing numerous cryptalgal thrombolite mounds is the setting envisaged for deposition of this formation. The peritidal lithologies at the top and bottom record periods of slowed subsidence relative to sea level.

Boat Harbour Formation

Formation stratotype: Shoreline (Figure 3a) from Boat Harbour 3.7 km northeastward along a rocky shoreline to a prominent 15-m cliff and wavecut intertidal terrace that is locally used to dispose of garbage (Raleigh map sheet, N.T.S. 2M/12, Grid Reference 570000 5716000 to 57280 571820).

Type locality: The name of this newly proposed formation is derived from Boat Harbour, a narrow bay near the northern tip of the Great Northern Peninsula (N.T.S. 2M/12, Raleigh map sheet).

Reference section: Cliffs and rocky shoreline on the west side of Isthmus Bay (Figure 3d) from a point 0.9 km south of the gravel bar northward to the south side of the bar (N.T.S. 12B/10, from 3700 5378500 to 372250 5379000).

Lithological character: Distinctively interbedded dark-grey limestones and lesser buff- to light-grey dolostones, which range through the full spectrum of textural rock types (Figure 5). These include flaser- and lenticular-bedded, thinly stratified and laminated, frequently shaly and mud-cracked, dolomitic lime mudstone and dolostone, sparsely to intensely bioturbated, often fossiliferous lime mudstone to packstone, intraclastic, skeletal to rarely oolitic lime grainstone, intraformational lime rudstone and several boundstone mound beds (Plates 2 and 3). The lithologies are arranged in a series of complete or partial shallowing-upward sequences.

A regional episode of subaerial exposure is present 17 to 36 m from the top of the formation in the form of one or more irregular exposure surfaces associated with chert and chalcedonic quartz-sand grains and pebbles, chert concretions, dolomite–chert breccia, resedimented breccia and dolomitization (Plate 2c, d and e). Distinctive repetitive sequences that occur above the disconformity are called the Barbace Cove Member. The member includes prominent ripple-marked, intraclastic–bioclastic grainstones intercalated in bioturbated, skeletal wackestones and packstones (Plate 3a, b); cycle tops are marked by mud-cracked, shaly, dolomitic limestones and dolostones (Plate 3c). Boundstone mounds are small and uncommon above the disconformity. Below the disconformity, the mounds which include both thrombolites and stromatolites are large and developed in several widely spaced horizons; grainstones are not prominent below the disconformity.

On the Great Northern Peninsula, the basal 30 to 50 m of the formation is extensively replaced by light grey, finely crystalline dolomite or pseudobreccia typified by relic dark grey domains, much porosity and white dolomite spar cements. Several dolostone–chert breccia beds (Plate 3d) are widely developed at the base of the formation on the Peninsula, and host Pb–Zn mineralization.

Thickness: 120 m at stratotype; 156 m at Isthmus Bay reference section.

Lower boundary: A conformable contact. On the Great Northern Peninsula, a blocky, dolostone and chert (locally pyritiferous) breccia of collapse or cavern origin occurs at many localities obscuring the contact relationship. Locally however, the contact is conformable with laminated, light grey dolostone resting on dark grey, diagenetic dolostone of the Watts Bight Formation. On the Port au Port Peninsula and in Canada Bay, the contact is placed beneath distinct, very thinly bedded limestone and minor dolostone that rests upon light grey, stromatolitic and thrombolitic mounds and cross-bedded grainstone of the Watts Bight Formation.

Lower boundary stratotype: north of Green Head, west side of Isthmus Bay, 0.9 km south of the gravel bar (N.T.S. 12B/10, Grid Reference 372000 5378500).

Lower boundary reference localities: 1) northwest point of Round Head Island, St. John Bay (St. John Island map sheet, N.T.S. 121/14, Grid Reference 48725 562875); 2) small cove, 0.9 km east of Fish Point, east shore of St. John Bay (St. John Island map sheet, N.T.S. 121/14, Grid Reference 49175 562475).

Upper boundary: Conformable. The boundary is placed at the top of the last thick bed of dolomitic, shaly lime mudstone or dololaminite that is intercalated with limestone and lies beneath the first thick, fossiliferous limestone of the Catoche Formation.

Upper boundary stratotype: Hunters Point (N.T.S. 121/14, Grid Reference 48459 56226).

Upper boundary reference localities; 1) east side of Barbace Cove (N.T.S. 121/11, Grid Reference 47465 561945); 2) west side of 'The Gravels,' Isthmus Bay, Port au Port Peninsula, (N.T.S. 12B/10, Grid Reference 372250 5379000).

Historical background: Parts or all of Richardson's divisions E, F and G (Logan, 1863; Schuchert and Dunbar, 1934) are encompassed in the Boat Harbour Formation. An incomplete section measured by Kluyver (1975) on Barbace Point, Port au Choix Peninsula and called the Barbace Point Formation, consists of the upper 50 m of the formation in the Port au Choix area. Levesque (1977) placed this unit in the upper part of his 'Lower Cyclic Member' of the St. George formation. Knight (1978) placed the limestones and dolostones into a separate formation from the overlying Catoche Formation in the Boat Harbour area. He referred to it informally as the 'unnamed unit' (Knight, 1978) and later (Knight, 1980b) informally as the Boat Harbour formation.

Dimensions and regional relationships: Rocks of the Boat Harbour Formation are well exposed in the north and along the west side of the Great Northern Peninsula and on the Port au Port Peninsula. The thickness of the formation appears to be consistent in these areas. Eastward the formation has been traced into parautochthonous rocks in Canada Bay and Hare Bay. There, however, the formation appears to be no thicker than 60 m (Knight and Saltman, 1980). In Hare Bay, parautochthonous strata believed to be partly equivalent to the Boat Harbour Formation were mapped as the Brent Island Formation (Stouge, 1983b) and estimated to be 140 m thick. In Goose Arm and Humber Arm, equivalent strata were placed in the Corner Brook Formation (Lilly, 1963; McKillop, 1963).

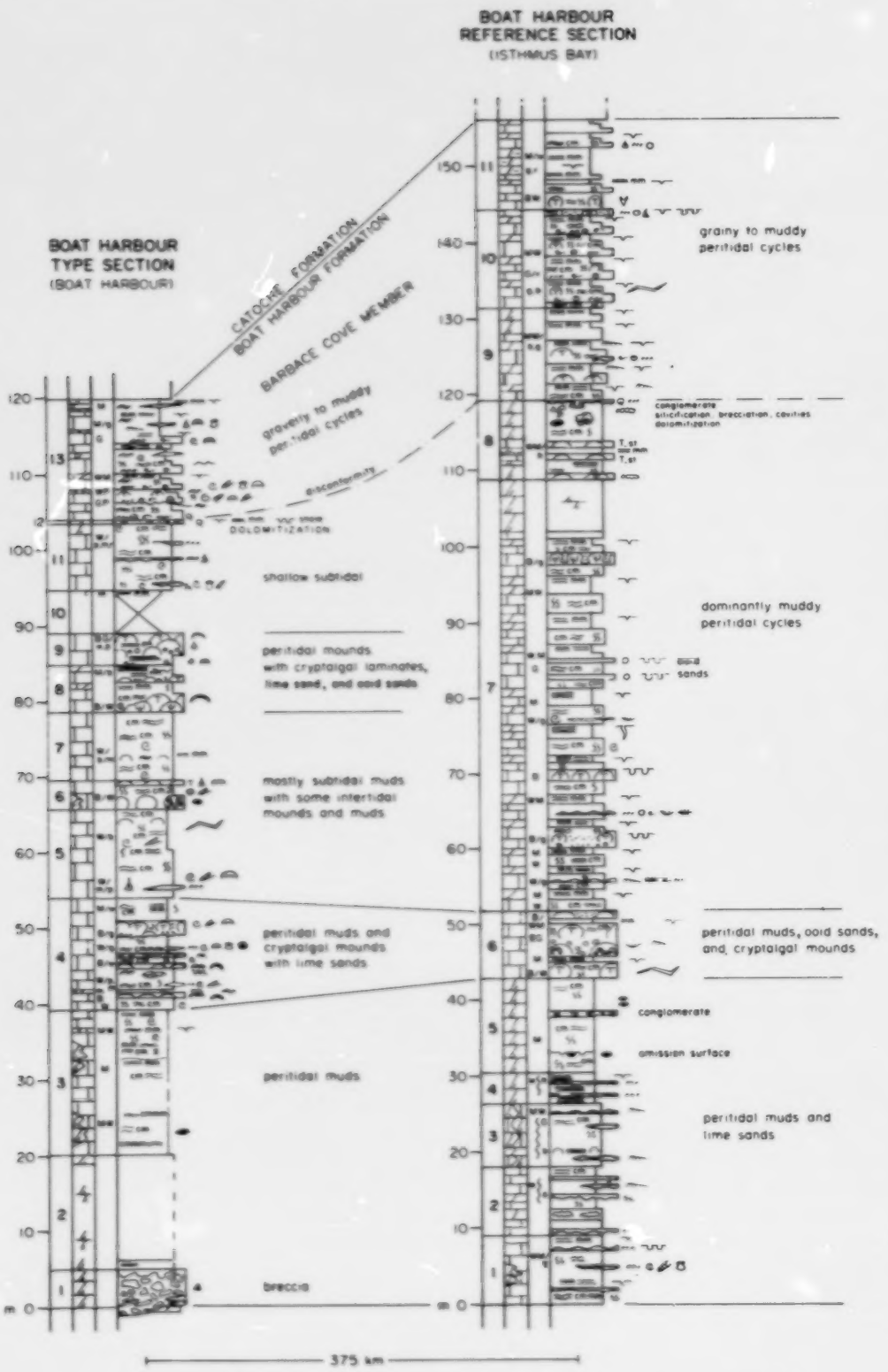


Figure 5. *Type and reference section of the Boat Harbour Formation (from Knight and James, 1987).*

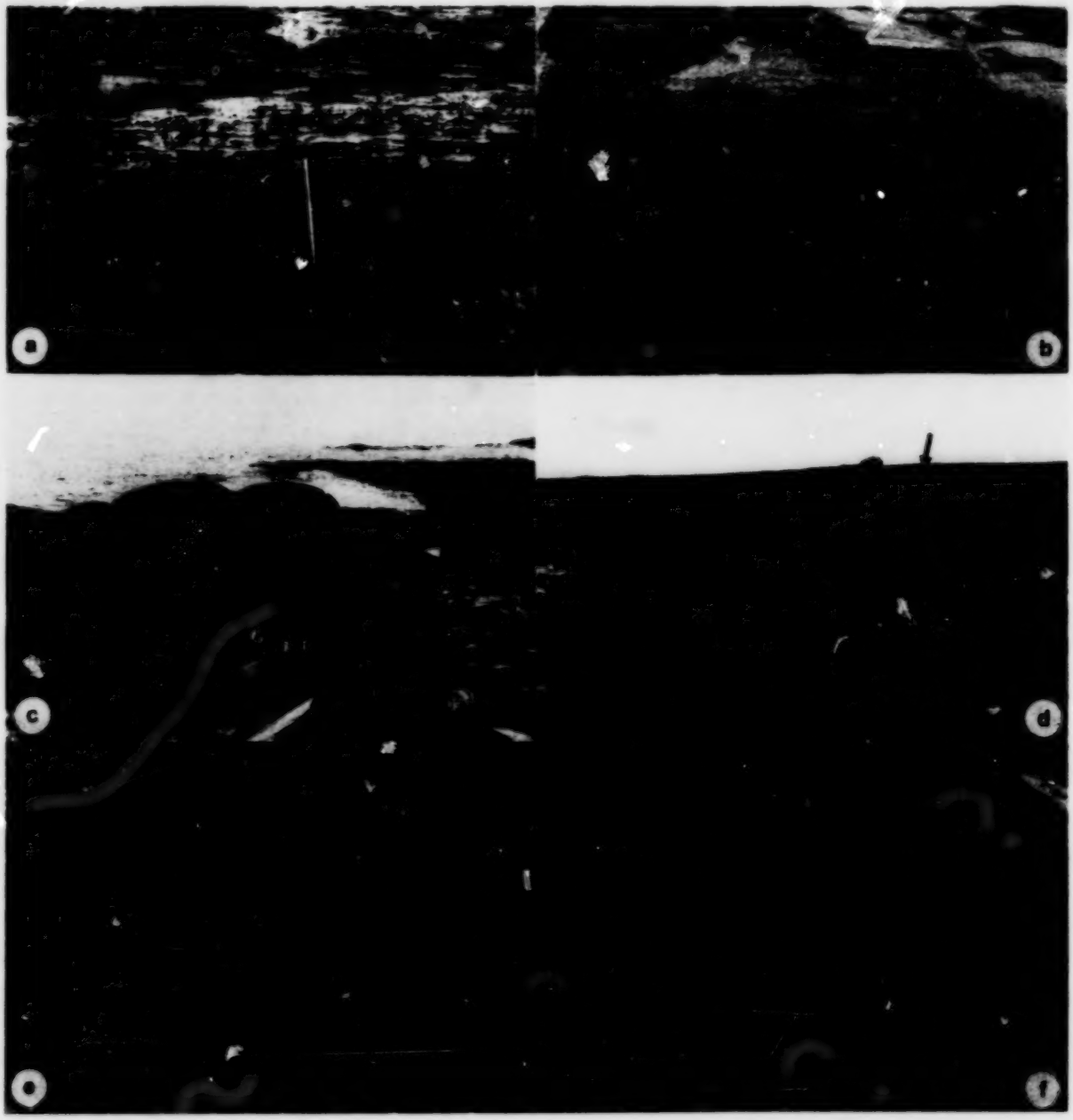


Plate 2. *Typical sedimentary features of the Boat Harbour Formation;* (a) *parted and flaser bedded dolomitic limestone that forms the top of a shallowing-upward cycle, overlain by burrowed wackestone of the next cycle (arrow), Eddies Cove West;* (b) *Dololaminite from the top of a shallowing-upward cycle, Eddies Cove West. The laminite is mudcracked and breached by fissure cracks;* (c) *thrombolite mounds arranged in linear banks and surrounded by skeletal-intraclastic grainstone, Eddies Cove West;* (d) *disconformity and overlying Barbace Cove Member at Boat Harbour. The pebble bed (lower arrow) separates underlying burrowed, locally dolomitized wackestone from grainstone to mudstone cycles above. The contact between the Boat Harbour and Cathoche formations is at the top of the upper ledge (upper arrow);* (e) *chert pebbles scattered in dolostones at the disconformity at Boat Harbour;* (f) *breccia developed upon dolomitized intermound mudstone and stromatolite mounds (not shown) marks the disconformity at Port au Choix (from Knight and James, 1987).*

Plate 3. *Sedimentary characteristics of the Boat Harbour Formation;* (a) *nodular and wavy bedded, parted limestones overlain by cross-stratified, skeletal–inuraclastic grainstone, Barbace Cove Member, Port au Choix;* (b) *ripple-marked grainstone, Barbace Cove Member, Hunters Point;* (c) *mud-cracked polygons in dololaminite, Green Island, Pistolet Bay;* (d) *collapse breccia, composed of blocks of massive, mottled and thinly stratified dolostone, base of the Boat Harbour Formation, Fish Point (from Knight and James, 1987).*

Characteristic fossils: Hystricurid, leiostegiid, asaphid trilobites (Boyce, 1983b), plani- and high-spired gastropods, cephalopods, ostracods, pelmatozoan echinoderms, orthid and inarticulate brachiopods, calcareous algae.

Age: Macrofossils and microfossils indicate that the formation is mostly Middle Canadian in age. Trilobites below the disconformity are assigned to Ross–Hintze Zones E and F of Utah and Nevada (Boyce, 1983b). Above the disconformity, the fauna in the Barbace Cove Member suggests an early Late Canadian age and contains trilobites of Ross–Hintze Zone G_2 (Boyce, 1983b). Examination of trilobites by Boyce (1983a,b) and conodonts by Stouge (1982) indicate that the disconformity separates two distinct faunas. Trilobites suggest that the disconformity coincides with the absence of Ross–Hintze trilobite zone G_1.

The conodont elements are assigned informally by Stouge (1982) to his faunas 2 and 3 that are both believed to be part of Midcontinent Fauna D of Ethington and Clark (1971) but are separated from each other by the disconformity. The lower fauna is characterized by *Macerodus dianae* Fahraeus and Nowlan and *Parapanderodus arcuatus* Ethington and Clark s.f. These two elements are absent in fauna 3, which contains diagnostic elements *Glyptoconus quadraplicatus* Branson and Mehl s.f., *Drepanodus parallelus* (Branson and Mehl) s.f., *Acodus?* sp.cf. *A. deltatus* Lindström and *Ulrichodina* sp.

The gastropods *Lecanospira* and *Ecculiomphalus* and cephalopods of the *Basseloceras* fauna of Flower (Flower, 1978) occur below the disconformity. *Pycnoceras apertum* faunas (Flower, 1978) occur above the disconformity, and below the *Cassinoceras wortheni* fauna of the Catoche Formation. These faunas, although based largely on preliminary collections, support the more precise biostratigraphic studies.

Depositional environment: The cyclic repetition of bioturbated, fossiliferous, muddy to locally grainy limestone with flaser-bedded limestone, cryptalgal laminite and mud-cracked, laminated dolomitic limestone and dolostone, plus beds of thrombolitic and stromatolitic boundstone mounds indicates that the Boat Harbour Formation records a prolonged interval of generally low-energy, muddy peritidal and shallow subtidal sedimentation. Shallow, open subtidal environments, intertidal carbonate mud flats, and higher energy subtidal, boundstone mound-dominated areas were present (Pratt and James, 1986). Late in the formation's history, subaerial exposure was accompanied by widespread stratigraphic dolomitization and silicification and the formation of siliceous sand and pebble lags, dolomite breccias and irregular, pitted solution surfaces. The flooded karst surface was covered by cyclic, shallow, dominantly low intertidal to supratidal sediments (Barbace Cove Member) deposited on mixed carbonate sand and mud flats.

Catoche Formation

Formation stratotype: Shoreline of Bustard Cove (Figure 3b) from Hunters Point (N.T.S. 121/14, Grid Reference 4845 56226) southwards 7.5 km to the east side of Back Arm (N.T.S. 121/11, Grid Reference 47635 56184). Rocky bay with ledges, wide bedding plane exposures, low cliffs and some sandy coves.

Type locality: Catoche Point, Port au Choix Peninsula (Kluyver, 1975) (Figure 3b).

Reference section: 1) Catoche Point to Blanche Point, western shore of Port au Choix and Pointe Riche peninsulas (Figure 3b) (N.T.S. 121/11, Grid Reference 47435 561935 to 47285 56184).

Lithological character: Well bedded, fossiliferous, bioturbated, grey limestones composed of mudstone to packstone with abundant, frequently ripple-marked, intraclastic, bioclastic grainstone lenses and thin beds (Figure 6, Plate 4). Body fossils are abundant in many beds and trace fossils are commonly dolomitized. Boundstone mounds are distributed at variably spaced intervals through the formation. They are composed of thrombolites, sponges, calcareous algae and rare corals associated with abundant sessile (eocrinoid) and vagile benthic organisms especially large cephalopods, gastropods and trilobites. Some mounds form linear banks with a north–south orientation. Sequences of massive mounds occur in the Pistolet Bay and Hare Bay areas (Figure 1, Plate 4d). Units of cross-bedded, intraclastic rudstone (Plate 4b) with imbricated, reddened, mudstone clasts, rare dolomitic parted limestones and thin laminated and, in some instances, mud-cracked, lime mudstone beds occur in the basal 12 m of the formation. Lime mottled, burrowed dolostone or dolomite-mottled lime wackestone beds occur at widely spaced intervals within the section at Catoche Point. A distinctive unit of light grey- to white-weathering, peloidal and fenestral limestones, 15 m thick, forms the top of the Catoche Formation in the Port au Port area and Pistolet Bay area and is called the Costa Bay limestone member.

Tan grey to dark grey, fine to coarsely crystalline dolomite replaces limestone of the upper 30 to 50 m of the formation in the type area (Plate 4e and f). The dolomites which are often rich in secondary porosity and white, coarse dolomite spar, occur in beds 0.6- to 3.0-m thick, that display little of the original rock fabric. Where fabrics are visible, vague planar to undulose thin stratification with some subhorizontal burrows occurs near the top and bottom of beds. Burrow mottling increases toward the centre of the beds and ghosts of gastropods occur. Light to dark grey, rubbly weathering limestone, locally containing trilobites, brachiopods and conodonts occur near the top of the dolostones at Back Arm and Table Point.

Dolomitization: The Catoche Formation has been affected to varying degrees by dolomitization that is areally extensive, especially on the Great Northern Peninsula. The dolostone is, in many places, multigenetic and the cumulative result of several different episodes of dolomitization (Haywick and James, 1984). In the simplest cases, only burrows and selected fossils are dolomitized. This fabric may be succeeded by dolomitization of the remaining limestone, leading to a dark to light grey, fine to medium crystalline, burrow-mottled dolostone. Locally the limestone between burrows may be replaced by medium crystalline saddle dolomite. Both of these rocks have been called pervasive dolostone. Finally, the last and most spectacular dolomite is coarsely crystalline, white saddle dolomite, which both precipitated into open voids or fractures and replaced limestone. In the Daniel's Harbour area, this dolomite was coeval with sphalerite formation.

From the type area around Port au Choix south to Table Point the upper 30 to 50 m of the Catoche is largely replaced by a complex series of dolomites. In general, the 0.6- to 3.0-m-thick beds are dark to light-grey burrow-mottled pervasive dolostone. Locally, these are interrupted by areas of extensive white saddle dolomite which may be bedding parallel or cross-cutting and clearly related to joints and fractures. In these zones of coarsely crystalline saddle dolomite, the fabric of the rock is complex; the dark burrow-mottled, pervasive dolostone occurs as irregular domains apparently floating in white saddle dolomite which in turn grows away from the dark dolomite into open voids. This rock has been called 'pseudobreccia' (Cumming, 1968) and is characteristically associated with sphalerite mineralization. This style of dolomitization is also found locally farther north. At Boat Harbour and Cape Norman, it occurs toward the base of the Catoche, and in Canada Bay and Hare Bay it occurs in the middle of the formation. In the south, the upper part of the Catoche is also dolomitized.

Thickness: 160 m at stratotype.

Lower boundary: Conformable contact with the underlying Boat Harbour Formation. The contact is placed above the last thick bed of laminated and mud-cracked, shaly dolomitic lime mudstone or dolostone of the Boat Harbour Formation and at the base of the first thick (40 to 100 cm), rubbly weathering, fossiliferous grey limestone (wackestone) of the Catoche Formation.

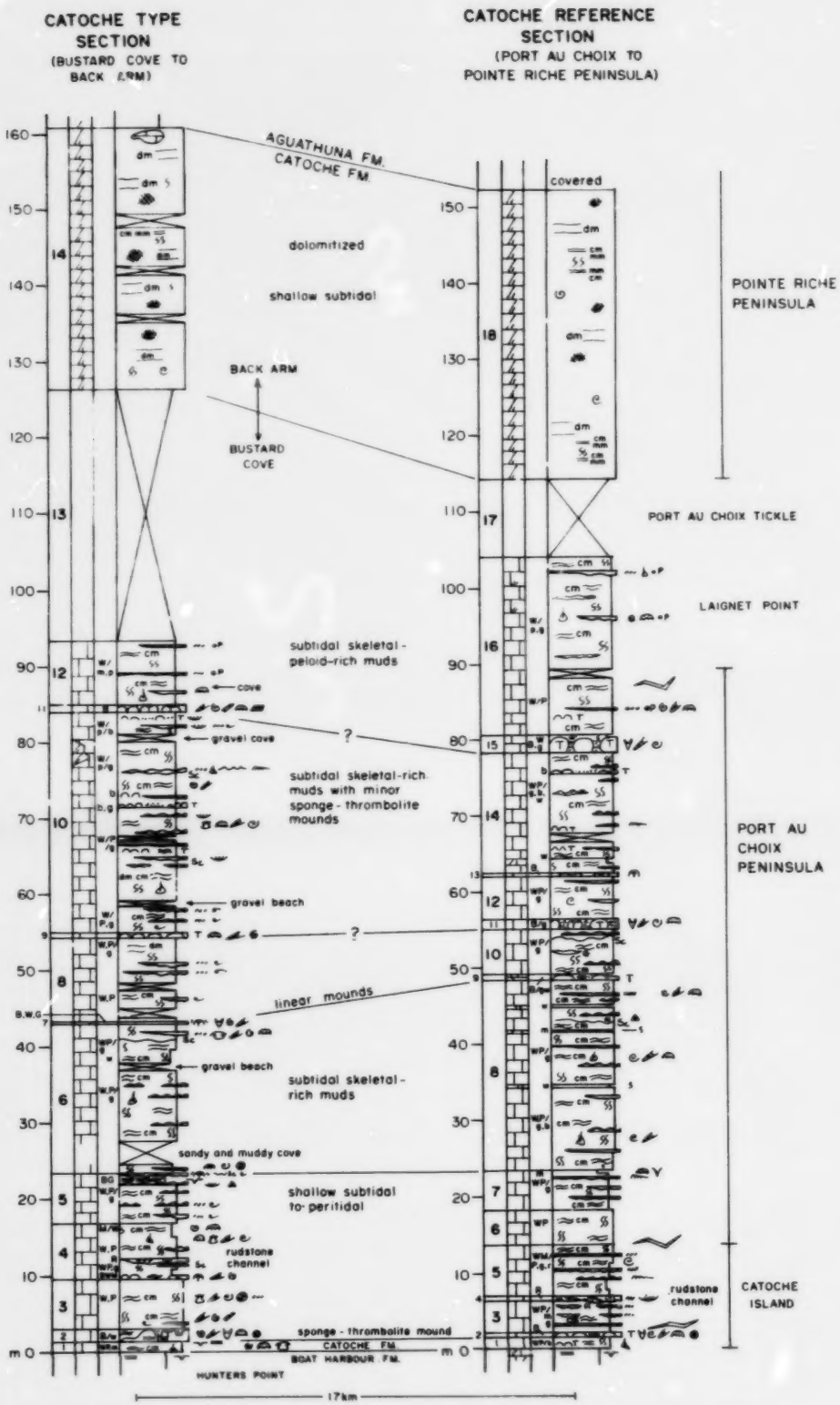


Figure 6. *Type and reference sections of the Catoche Formation (from Knight and James, 1987).*

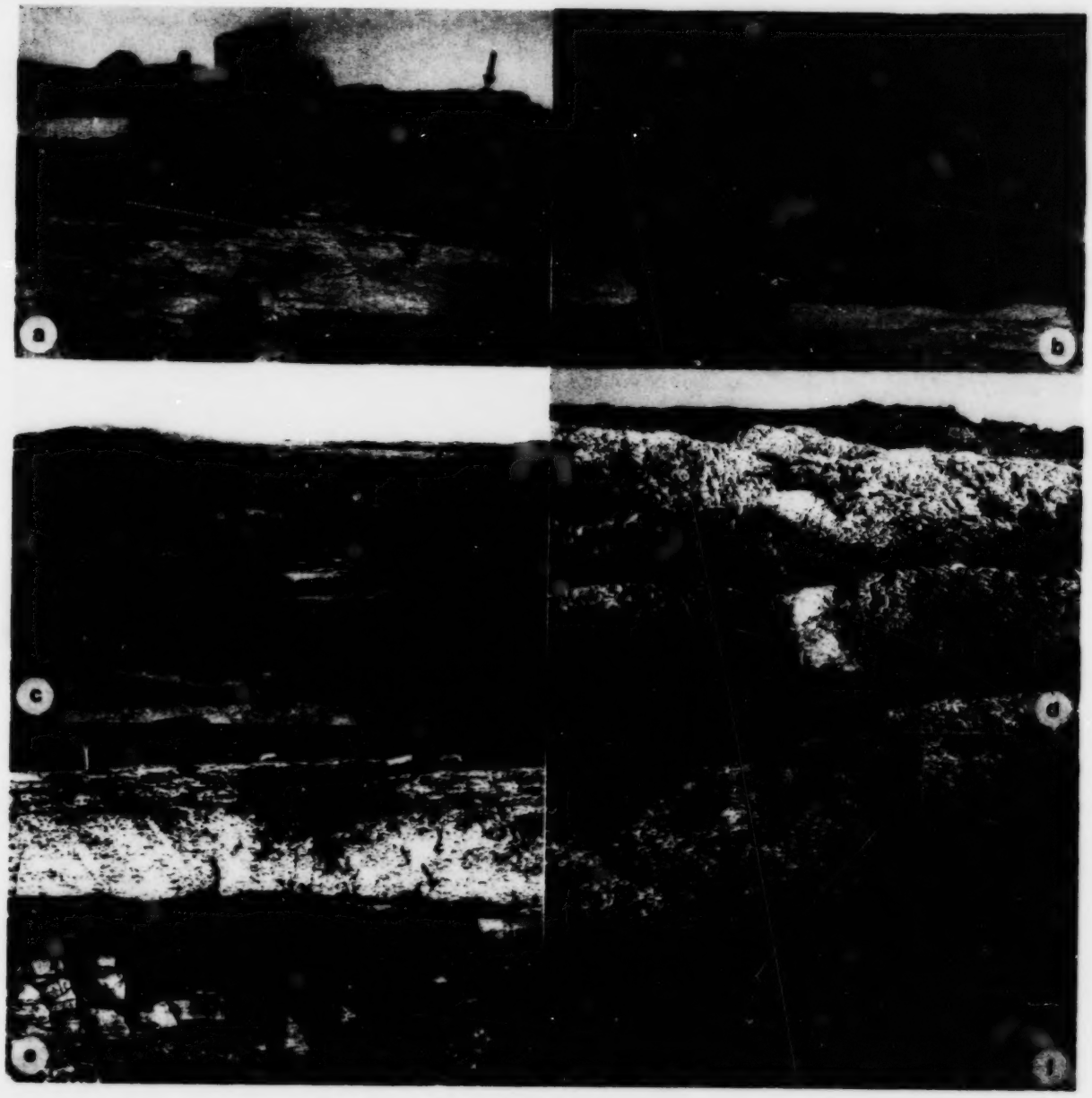


Plate 4. *Typical sedimentary features of the Catoche Formation;* (a) *contact of the Boat Harbour and Catoche Formation (at feet of geologist) at Hunters Point. Burrowed and mounded (arrow) limestone forms the basal strata of the Catoche Formation;* (b) *a cross-stratified rudstone with a drape of wackestone within the cosets, interbedded within thinly bedded wackestones to grainstones, Catoche Point;* (c) *typically bedded Catoche limestones with scours (Sc) and lenses of skeletal–intraclastic grainstones (arrows), some with ripple-marked tops;* (d) *massive thrombolite mounds, Pistolet Bay;* (e) *intercalated massive dolostone and 'pseudobreccia', Deer Cove;* (f) *white sparry dolomite within burrow-mottled, sucrosic dolostone, Deer Cove (from Knight and James, 1987).*

Lower boundary stratotype: Hunters Point (Plate 4a) (N.T.S. 12I/14, Grid Reference 48459 56226).

Lower boundary reference localities: 1) east side of Barbace Cove (N.T.S. 12I/11, Grid Reference 47465 561945); 2) Catoche Point (N.T.S. 12I/11, Grid Reference 47435 561940); 3) west side of 'The Gravels,' Isthmus Bay, Port au Port Peninsula (N.T.S. 12B/10, Grid Reference 372250 5379000).

Upper boundary: Conformable contact with the overlying Aguathuna Formation. The contact is placed above the last bed of well bedded, finely crystalline, diagenetic dolostone and below the first bed of yellow-weathering, bedded, grey to light grey microcrystalline dolostone.

Upper boundary stratotype: south of Deer Cove (N.T.S. 12I/5 & 6, Grid Reference 462255 557985).

Upper boundary reference locality: east side of Back Arm (N.T.S. 12I/11, Grid Reference 47595 561795).

Historical background: Division H (but also parts of F) of Richardson (Logan, 1863; Schuchert and Dunbar, 1934) are synonymous with the limestone of the Catoche Formation. Division I (but also parts of G) of Logan (1863) are synonymous with the upper dolostone of the formation, which was later called the Port au Choix Formation by Kluyver (1975). The formation was called the 'Middle Limestone Member' of the St. George by Levesque (1977) who first recognized that it occurred as a distinctive unit throughout western Newfoundland.

Kluyver (1975) designated the section from Barbace Cove, south to Port au Choix Cove, as the type section. The base of this section is cut by a number of high angle faults that have both vertical and lateral displacement. As a result, there is structural repetition of some beds in his section, and a further comparison of the sections he used to compose his composite section, show that several metres of strata are missing. It is also not clear from his composite diagrammatic section if his basal contact coincides with that defined in this study. Therefore, we prefer to designate the Bustard Cove section as the formation stratotype since this section is structurally and stratigraphically continuous except for a covered interval (that is also poorly exposed at Port au Choix) near the top of the limestones.

Also included in the revised Catoche Formation are the dolostones of Kluyver's (1975) Port au Choix Formation. Depositional fabrics and rare relics of unaltered limestone in these dolostones confirm that the original carbonates form a continuum with the underlying limestones.

Dimensions, regional relationship and correlation: The Catoche Formation is readily identified throughout western Newfoundland. It has not yet been delineated northeast of Stephenville through to Goose Arm, where deformation makes differentiation difficult. In this region, however, it is clearly part of the Corner Brook Formation (Lilly, 1963; McKillop, 1963).

At Cape Norman, at the northern tip of the Great Northern Peninsula, approximately 40 m of section is present with a good basal contact with the Boat Harbour Formation; no top is known and much of the section is affected by dolomitization. Limestone and dolostone of the Catoche Formation have been mapped in Canada Bay in both autochthonous and parautochthonous rocks and the formation is up to 220-m thick. In the Hare Bay area, the formation is mapped in the autochthon and parautochthon.

Equivalent strata in the parauthochthonous thrust zone of the area, however, have been placed in the Southern Arm Formation by Cooper (1937) and Stouge, (1983b). We suggest that this name be dropped from current usage in favour of Catoche Formation. Peculiar to the Southern Arm Formation are abundant cryptalgal–sponge? boundstone mounds (Stevens and James, 1976; Stouge, 1983b). Stouge (1983b) estimated the formation to be 270 m thick and subdivided it into alternating members of bedded, bioturbated limestone and mounded limestone associated with micritic limestone and dolostone. A fifth and uppermost member of cyclic dolostone and dolomitic limestone, originally placed by Cooper (1937) in the overlying Table Head Formation (Cooper's, Hare Bay limestone), is included by Stouge (1983b) in the Southern Arm Formation. This member directly underlying Table Head limestones is in the new terminology, the Aguathuna Formation. The distinct mound limestones also occur extensively in parautochthonous rocks on Schooner and Burnt Islands, Pistolet Bay and Canada Bay (Knight, 1986, 1987).

In Humber Arm and Goose Arm, strata equivalent to the Catoche Formation are contained in the Corner Brook Formation of Lilly (1963) and McKillop (1963). On the Port au Port Peninsula, the Catoche Formation was mapped by Besaw (1974) as the White Hills unit of the St. George Group. It is at least 160 m thick and is also well exposed on Table Mountain, northwest of Stephenville. The Costa Bay limestone member, which forms the top of the Catoche in the Port au Port area, was originally called the Pine Tree unit by Besaw (1974).

Characteristic fossils: Bathyurid, asaphid, dimeropygid, lecanopygid and pliomerid trilobites (Fortey, 1979; D. Boyce, personal communication, 1984), planispiral and high-spired gastropods, opercula, orthoconic to cyrtoconic cephalopods, ostracods, pelmatozoan echinoderms, sponges, receptaculitids, corals, calcareous algae, graptolites, orthid and inarticulate brachiopods.

Age: Trilobites indicative of Ross–Hintze trilobite Zones G_2 to J, have been recovered from the Catoche Formation (Fortey, 1979; Boyce, 1983a) suggesting it is exclusively late Canadian (Cassinian) in age. Conodonts (Stouge, 1982) and rare graptolites (Cumming, 1967; Boyce, 1985; Williams *et al.*, 1987) confirm this age assignment.

Depositional environment: The Catoche Formation is a package of dominantly open shelf subtidal limestones. Shallow, peritidal settings prevailed during the early stages of deposition in which channel-bound and storm-generated intraclastic rudstones, tidal flat parted limestones and mud-cracked, laminated lime mudstones, and subtidal small sponge–thrombolite mounds and fossiliferous mudrocks accumulated.

The rest of the formation, however, characterized by bioturbated, stratified limestone rich in a diverse benthic fauna, typifies an open subtidal shelf setting. Ripple-marked, bioclastic and intraclastic grainstone reflects the influence of wave- or storm-generated bottom currents reworking and sorting the sea floor bottom. Major storms scoured the bottom muds producing cross-cutting surfaces. Lithified intraclasts suggest sea-floor cementation and hardgrounds. Cryptalgal–sponge–rare coral, boundstone mounds flourished in different areas of the shelf. To the east, the thick, continuous development of these mounds suggests they formed a prominent, probably high-energy, barrier facies, on the more outboard, eastward part of the shelf. The presence of algae such as *Renalcis* (Pratt and James, 1982) suggests that the mounds flourished together with a large benthic fauna within the photic zone, and hence suggest water depths of no more than several metres. A more restricted fauna, fenestral limestones and some cyclicity toward the top of the formation, and the passage upward into peritidal, probably more restricted deposits of the overlying Aguathuna Formation, suggest the shelf shallowed as deposition began to outpace relative subsidence.

Aguathuna Formation

Formation stratotype: Shoreline just north of Table Point (Figure 3c) where it is exposed in an intertidal, wave-cut terrace backed by discontinuous, vegetation-covered storm cobble beaches and cliffs (N.T.S. 12I/5 & 6, Grid Reference 462255 557985 to 461900 557950).

Type locality: Originally named after the incomplete section exposed in the Aguathuna limestone quarry (Figure 3d) on the north side of the Port au Port Peninsula (N.T.S. 12B/10, Grid Reference 369250 5380000).

Reference section: Western shoreline (Figure 3d) of East Bay, Port au Port Peninsula along an intertidal platform and low cliff, north of the gravel isthmus ('The Gravels') (N.T.S. 12B/10, Grid Reference 372250 5379600 northward to Grid Reference 372000 5379800).

Lithological character: Dolostone, limestone and shale are characteristic of the formation (Figure 7). Dolostone and shale form the type section although calcareous dolostone occurs at the top of the section. Limestone and shale are intercalated with the dolostone in the reference section.

The dolostone units are buff-, tan- to light-grey-weathering, green–grey to pale grey, generally microcrystalline with common chert. The strata are commonly arranged in sequences of thick-bedded, burrowed dolostone (Plate 5a) capped by planar, thinly stratified and laminated dolostone and/or dololaminite (Plate 5b). The upper dolostone is intercalated with shale and displays mud-cracks, small ripple marks and intraformational breccia pavements and lenses. Intraformational breccia commonly containing quartz sand grains and pebbles occur at the base of several sequences that may also contain stromatolitic dolostone. Beds up to 60 cm thick of crudely stratified, conglomerate with chert and dolostone pebbles occur above extensively brecciated and silicified dolostone 8 to 16 m from the top of the formation at River of Ponds Lake, Table Cove and Portland Creek Pond (Plate 5c) (Knight, 1985). Shale units are commonly green, grey and red, finely laminated, dolomitic, mud-cracked and recessively weathered. Limestone units in the reference section include grey lime mudstone to packstone with some bioclastic and oncolitic rudstone. Limestone units that are locally fossiliferous include burrowed, laminated and cross-laminated beds, thrombolitic, stromatolitic and cryptalgal laminated boundstones, chert and hardgrounds. Two beds of angular dolostone and/or limestone–chert breccia associated with chert fragments, green shale and stromatolitic dolostone, occur both in the type section and reference section. Fractures and small to large collapse breccias, some of early syndepositional origin, locally affect the dolostones of the formation in the Port au Choix area and east of Table Point (Knight and Boyce, 1984; Lane, 1984).

Thickness: 63.1 m at stratotype.

Lower boundary: Apparently conformable at the type section, where it is placed at the base of grey to light grey, finely crystalline, bioturbated and laminated dolostone that overlies dark grey dolostone of the Catoche Formation. However, at a locality on River of Ponds Lake, the formation rests with irregular disconformity upon brecciated, silicified dolostone of the Catoche Formation.

Lower boundary stratotype: Freshwater Cove, south of Deer Cove (N.T.S. 12I/5 & 6, Grid Reference 462255 557985).

Lower boundary reference localities: 1) Back Arm (N.T.S. 12I/11, Grid Reference 47595 561795); 2) quarry west of large Aguathuna Quarry (N.T.S. 12B/10, Grid Reference 369250 5379500).

Upper boundary: At the type section, the contact is placed where thick bedded, white weathering, blueish grey, calcareous dolostone is overlain conformably by blueish grey, nodular limestone of the Table Point Formation, Table Head Group (Plate 5d). At the reference section, the contact is placed at the top of tan-weathering, massive dolostone that is overlain by grey, fenestral cryptalgal laminite and lime mudstone of the Table Point Formation. Although in the narrow shoreline section at East Bay, it is apparently conformable, 3 km to the west in the Aguathuna limestone quarry, an unconformity with 8 m of erosional relief is present (Plate 5e, f).

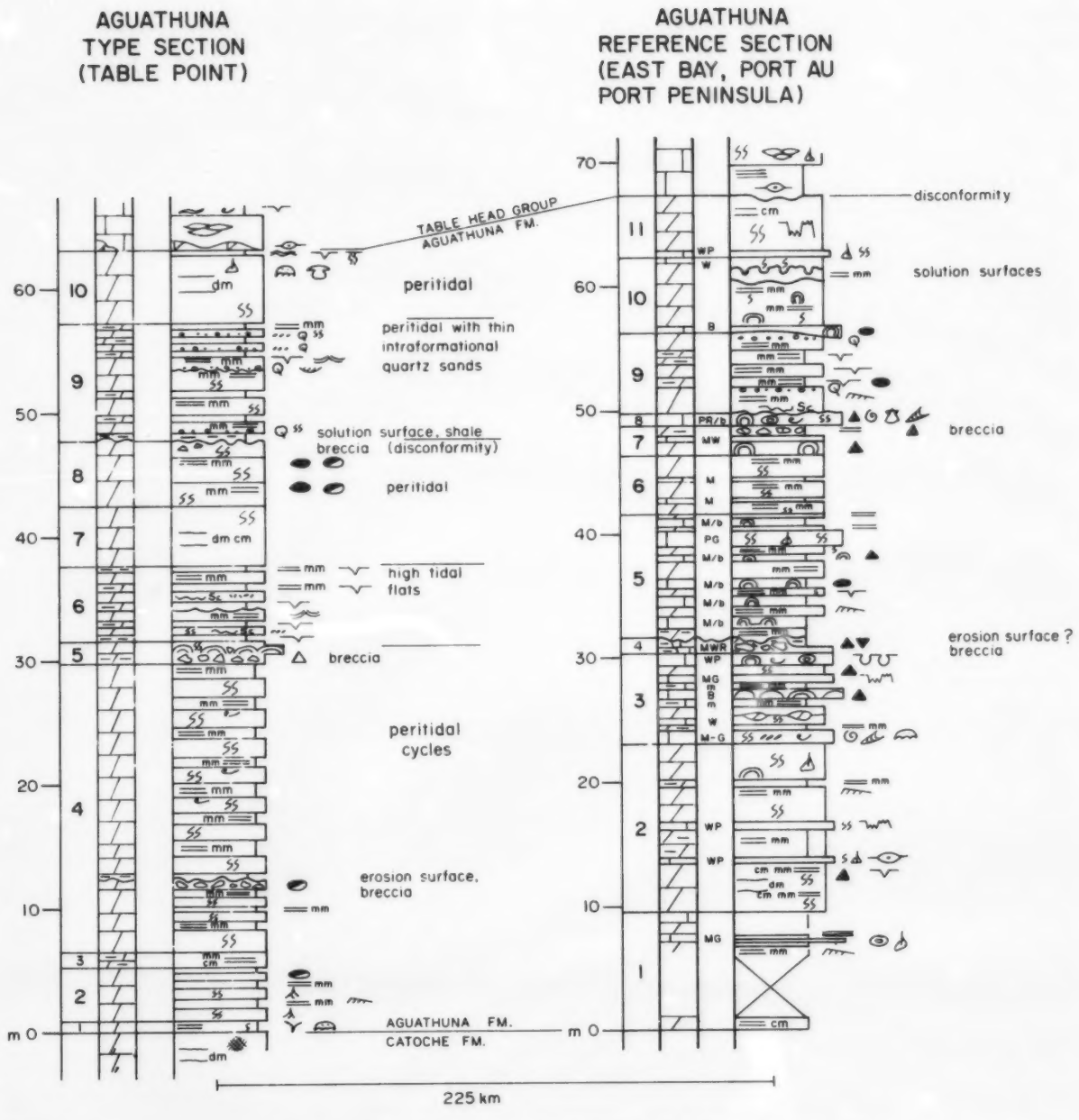


Figure 7. *Type and reference sections of the Aguathuna Formation (from Knight and James, 1987).*

Upper boundary stratotype: Table Point (N.T.S. 121/5 & 6, Grid Reference 461900 5579500).

Upper boundary reference locality: 1) Aguathuna quarry (N.T.S. 12B/10, Grid Reference 369250 5380000); 2) East Bay, Port au Port (N.T.S. 12B/10, Grid Reference 372000 5379800).

Historical background: This interval was not identified separately by Richardson though it is likely included in Division I and perhaps G (Logan, 1863; Schuchert and Dunbar, 1934). Kluyver (1975) also failed to identify it at Port au Choix but in the area of Daniel's Harbour, it was referred to as Cyclic dolomite (Collins and Smith, 1975). Levesque (1977) designated this unit as the 'Upper Cyclic Member' of the St. George Formation. Knight (1977) informally referred to it at Table Point as the Siliceous dolomite formation and later also informally as the Bellburns formation (Knight, 1980b). On the Port au Port Peninsula, the formation was

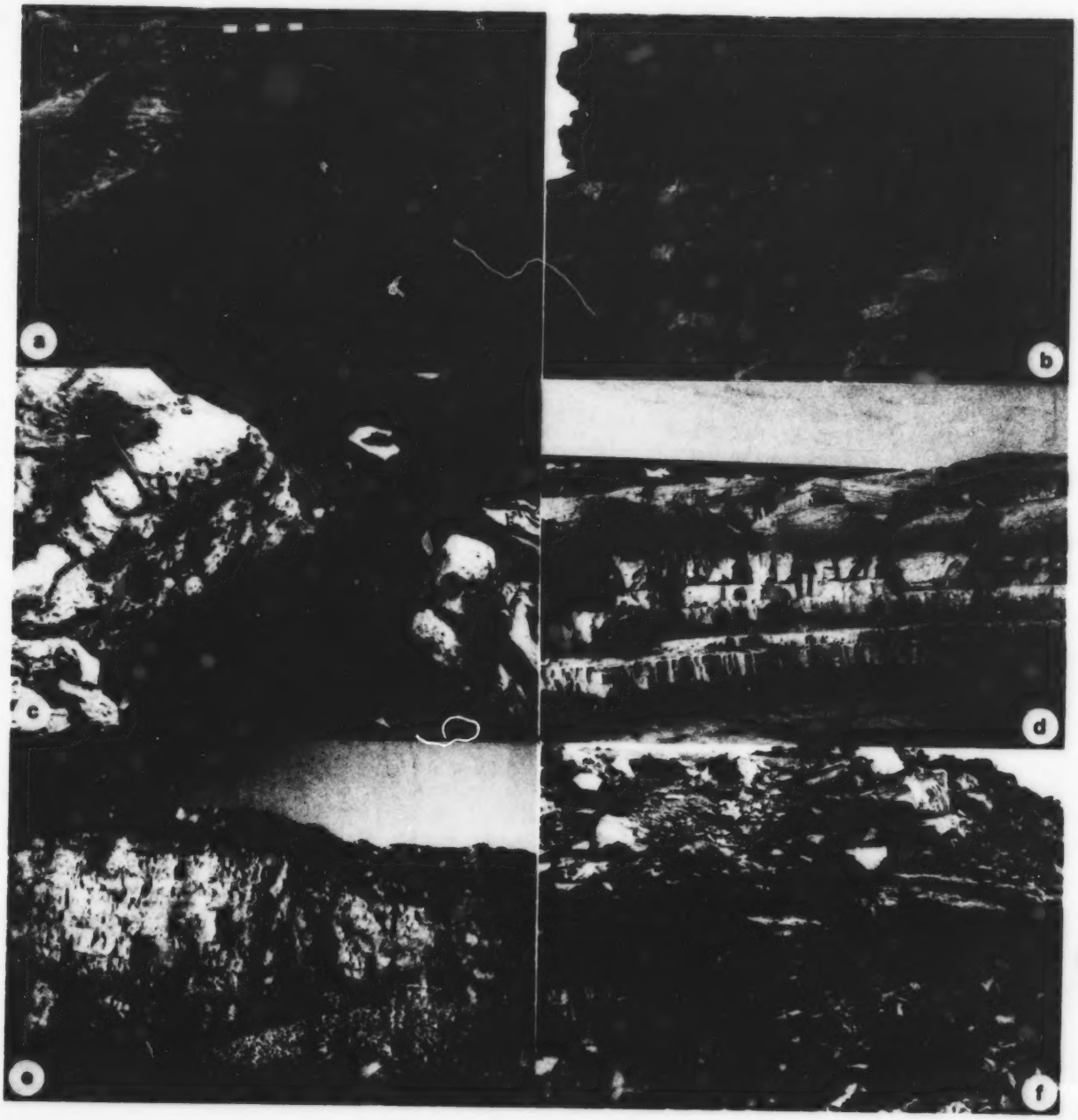


Plate 5. *Sedimentary characteristics of the Aguathuna Formation; (a) dolostone displaying mottled and laminated structure, East Bay; (b) cycles of bedded dolostone and shale, Table Point; (c) intraformational disconformity marked by a bed of massive, stratified, chert–pebble conglomerate overlying silicified and brecciated dolostone, Portland Creek Pond (beds are inverted); (d) contact (arrow) of the Table Head Group with the Aquathuna Formation, Table Point; (e) erosional disconformity (arrow) at top of the Aguathuna Formation, Aguathuna Quarry. Table Point limestones overlie the downcutting surface; (f) close-up of the erosional disconformity, Aguathuna Quarry. A chert–dolostone breccia is developed at the top of Aguathuna dolostones (arrow) and together they are cross cut by the erosion surface that is overlain by Table Point limestone (from Knight and James, 1987).*

mapped as the Port au Port unit of the St. George Group by Besaw (1974).

Regional aspects: Variation of thickness, lithology and age characterize the Aguathuna Formation. At Back Arm, and on Horn Island just east of St. John Island, the formation is only 5 m thick, compared to 63 m at Table Point, 40 km to the south. On the west and east shores of River of Ponds lake, which occurs midway between these two areas, sections 4 km apart, contain approximately 15 m and 60 m of strata respectively (Knight, 1985). On the Port au Port Peninsula, the formation is thicker than 67 m. In the Pistolet Bay area, the formation varies from 7 to 16 m in thickness. It is absent between the Catoche and Table Head formations on Burnt Island (Knight, 1986) and locally in Canada Bay (Knight, 1987).

Lithologically, in the type area and near Port au Choix, the formation consists of dolostone and shale. It also contains limestones on the Port au Port Peninsula, and correlative rocks near Hare Bay comprise limestone and dolostone (Stouge, 1983a; Knight, 1986). Equivalent strata in parautochthonous rocks near Main Brook, Hare Bay have been placed in the upper member of the Southern Arm Formation by Stouge (1983b).

Characteristic fossils: Cephalopods and gastropods are most common. Conodonts (Stouge, 1982), rare trilobites, and some graptolites (Collins and Smith, 1975; Levesque, 1977; Cumming, 1967; Williams *et al.*, 1987) also are present.

Age: Conodonts recovered throughout the formation on the Port au Port Peninsula give a Canadian age and are believed to be transitional between Midcontinent Fauna E and Midcontinent Fauna 1 (Stouge, 1982). The graptolites *Didymograptus (Extensograptus) extensus* and *Didymograptus (Extensograptus)* ex. gr. *nitidus* (H. Williams, personal communication, 1984; Williams *et al.*, 1987) occur in the lowest beds of the Aguathuna Formation at Table Point. These forms, which occur in Bendgonian 2 to Chewtonian 2 faunules of Australia, suggest a late Canadian age. They compare with graptolites recovered from mid-bed 11 of the Cow Head Group which are associated with trilobites of Ross–Hintze zone I.

However, conodonts (Stouge, 1982) and trilobites (Boyce, 1983a; R.A. Fortey, personal communication, 1984; R.J. Ross, personal communication, 1984) recovered from the top of the formation on the Northern Peninsula suggest an early Whiterockian age. The conodonts belong to the Midcontinent Fauna 3 and 4 (Stouge, 1982). The trilobite *Bathyurus perplexus* occurs in the upper beds of the formation at Back Arm and Table Point (Boyce, 1983a). The trilobite *Acidiphorus* cf. *A. pseudobathyurus* has also been recovered from the uppermost beds of the formation at Table Point (R.A. Fortey, personal communication, 1984) and Big Springs Inlet, Hare Bay (R.J. Ross, personal communication, 1984).

Depositional environment: The cyclic nature of the formation characterized by sequences of bioturbated carbonate overlain by mud-cracked, laminated carbonate, and the presence of stromatolites, suggests deposition in a predominantly intertidal–supratidal flat setting. Uneven, cherty solution surfaces, syndepositional intraformational breccia and rudstone suggest subaerial exposure in which weathering, dissolution and diagenesis affected the dominantly carbonate mudrocks. Paleokarst surfaces and rubble zones were produced during subaerial exposure, and material was reworked into the base of succeeding transgressive depositional phases.

DISCUSSION

The stratigraphic succession present in the St. George Group is the amalgamation of two unconformity-bounded megacyles. Each megacyle is characterized by the same general sequence of deposition; 1) basal peritidal sediments, 2) middle subtidal facies, and 3) upper peritidal deposits (Figure 8).

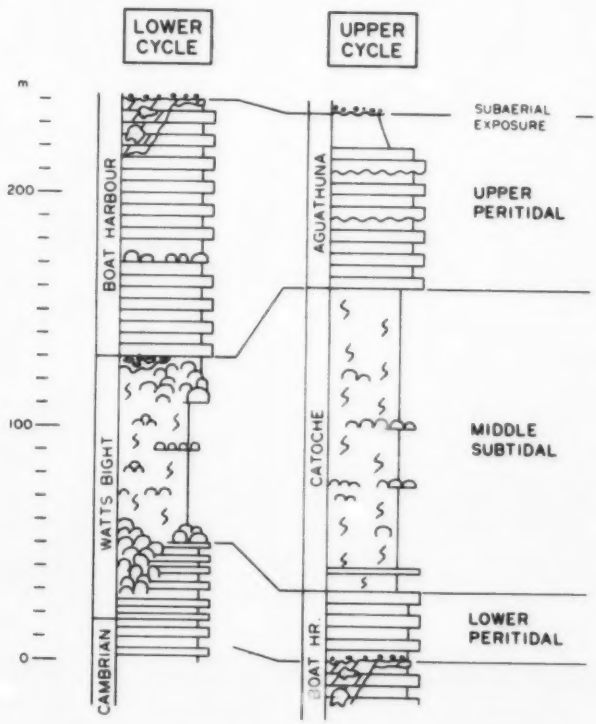


Figure 8. *Simplified diagram illustrating the two megacycles that comprise the St. George Group (from Knight and James, 1987).*

The succession of sediments within each megacycle is a record of the relative rate of carbonate sedimentation compared to the relative rate of sea-level rise, which is the combination of shelf subsidence and eustatic fluctuations in sea level.

LOWER MEGACYCLE

The lower megacycle of early to middle Canadian rocks (Tremadocian) comprises the Watts Bight Formation and most of the Boat Harbour Formation. It terminates at a subaerial exposure unconformity near the top of the Boat Harbour Formation.

In the area of the Port au Port Peninsula, peritidal deposition, already established in latest Cambrian strata throughout western Newfoundland, persisted into the basal part of the Watts Bight Formation as numerous shallowing-upward sequences and forms the base of the lower cycle. The overall environment was relatively shallow, with open-marine, subtidal, muddy sediments between algal mound complexes, and widespread tidal flats. Farther inboard in the St. Barbe region and at Canada Bay, the shelf was more consistently subtidal and is marked by large boundstone mound complexes that overlie an extensive unit of bioturbated, thinly stratified, muddy carbonate. A shelly fauna of Gasconadian cephalopods and gastropods occurs in these subtidal strata. Nevertheless, the presence of peritidal dolostone caps on mound complexes in the St. Barbe area still indicate very shallow deposition.

The middle subtidal sediments of the first megacycle comprise most of the Watts Bight Formation. It is a subtidal carbonate, wholly dolomitized in the north consisting of mainly muddy to grainy sediment that is extensively burrowed. Small thrombolite–metazoan mounds and reefs surrounded by skeletal sands are found throughout but are particularly prominent near the base and top. The generally subtidal sediments are interrupted by occasional peritidal horizons. Overall, the record is one of carbonate production keeping pace with, or just lagging behind, relative sea-level rise in a very shallow shelf setting.

The upper deposits comprise the lower two thirds of the Boat Harbour Formation, which is a Demingian sequence of metre-scale, peritidal, shallowing-upward sequences that developed as sedimentation kept pace with or exceeded relative sea-level rise. Predominance of muddy tidal flat sediments in these rocks, which have lithofacies that range from subtidal to supratidal, prompted Pratt and James (1986) to suggest that the sequences were formed as tidal flat islands closely comparable to present-day Florida Bay (Enos and Perkins, 1979). These islands studded the shallow platform and developed as storms and tides produced mudbanks that accreted vertically to and above sea level. They enlarged by lateral accretion with tidal flats prograding over the shallow subtidal shelf. A small but varied fauna of trilobites, brachiopods, gastropods, cephalopods and pelmetazoans diversified on the shallow sea floor to occupy niches within different subenvironments, particularly the boundstone mounds (Pratt, 1979; Boyce, 1983b).

The top of the megacycle is bounded by a horizon of subaerial exposure, featuring solution surfaces, dolomitization, silicification, intraformational dolomite and/or chert breccias and lag deposits composed of intraformational quartz sand and pebbles. At Boat Harbour, on the Great Northern Peninsula, this zone appears to coincide with a single prolonged event characterized by a pitted subaerial exposure surface, intraformational quartz pebble and sand lag (the insoluble residue from dissolution of carbonate) and a thin underlying zone of dolomitization. Chert–dolostone breccia and stratified conglomerate occurs in the Port au Choix and River of Ponds area (Knight, 1985a, *in preparation*). On the Port au Port Peninsula, the same stratigraphic interval contains several dissolution surfaces, caverns with dolomite collapse breccia, resedimented siliceous and dolomite conglomerates above an extensive zone of dolomitization, suggesting repeated episodes of sedimentation and subaerial exposure. Trilobite faunas typical of the lower Boat Harbour Formation die out at this surface (Boyce, 1983b) and there is a major change in the conodonts (Stouge, 1982) and gastropods above and below the surface, throughout the Great Northern Peninsula. According to Boyce (1979, 1983a,b), the break coincides with Ross–Hintze trilobite Zone G_1 and hence occupies much of the Jeffersonian. No detailed biostratigraphic studies of the faunas in the Port au Port area have been undertaken to date.

The transition into the peritidal sediments of the Boat Harbour Formation from the Watts Bight Formation, although conformable, is marked extensively in the north by intraformational breccia. This breccia, composed of clasts of coeval and overlying strata, has all the characteristics of a collapse breccia of later subsurface carbonate karst. The dissolution of interstratal evaporites seems unlikely because there is little evidence of evaporite deposition in the St. George Group, apart from a few small silicified and dolomitized crystals and nodular pseudomorphs after anhydrite in peritidal sediments.

UPPER MEGACYCLE

The upper megacycle of Upper Canadian (Arenig) and Whiterockian age comprises the upper part of the Boat Harbour Formation, the Catoche Formation and the Aguathuna Formation.

The basal beds of this megacycle, lying immediately upon the disconformity surface, are 24 to 50 m of cyclic, subtidal to supratidal sediments with a rich, mixed, shelly fauna. This interval includes the top 17 to 36 m of the Boat Harbour Formation (Barbace Cove Member) and the basal 12 to 15 m of the Catoche Formation. Low energy sediments such as burrowed mudstone to packstone and peritidal mud-cracked, shaley, dolomitic lime mudstone and cryptalgal laminite were laid down in tranquil, shallow subtidal and adjacent intertidal environments. Rudstone-filled channels crossed the tidal flats where periodic storm events swept coarse detritus into the setting and formed the ripple-marked beds of skeletal–intraclast grainstone to rudstone.

Faunas of the Barbace Cove Member differ from those below the Boat Harbour disconformity and are closely allied to those of the overlying Catoche Formation (Boyce, 1983b,

personal communication, 1984). This suggests that these cyclic strandline deposits were the first deposits laid down during the initial stages of renewed platform flooding. A thicker succession of cyclic peritidal carbonates (36 m) of the Port au Port Peninsula, compared to the Great Northern Peninsula (12 to 23 m) suggests this phase may have begun sooner on the outer shelf, now preserved in the south, than in the north–west and that subsidence of the outboard areas of the platform was greater at this time.

These peritidal sediments of distinctively higher energy origin than in the rest of the St. George Group, indicate both that carbonate sediment production kept pace with relative sea-level rise and that high energy extended well onto the platform, and was not damped by a barrier.

The middle subtidal part of the upper megacycle consists of the next 90 m of well-bedded, fossiliferous limestones of the Catoche Formation. Carbonate muds with numerous storm-generated sand lenses hosted a burrowing and diverse, shelly, benthic fauna. Trilobites include those evolved from inner shelf forms (Fortey, 1979; Boyce, 1983b, personal communication, 1984) and some of deeper water, off-shelf affinity, which migrated onto the shelf as sea-level rise continued and shelf water deepened (Fortey, 1979).

Based upon the trilobites Fortey (1979) recovered from this section of the Catoche Formation, he argued for a shallow shelf sea inhabited by benthic shelf-loving forms. The presence of the pelagic trilobites *Carolinites* and *Opipeuter* and the graptolite *Clonograptus*, (Cumming, 1967) suggested to Fortey that the shelf also possessed connections to the open ocean. Large bank complexes of thrombolites, calcareous algae, sponges, primitive corals, pelmatozoans and large shelly faunas studded the shelf at this time. In more outboard areas, such mounds locally appear to form a major mound barrier complex as seen in the parauthochthonous rocks of the Hare Bay and Pistolet Bay region. The linear mounds and ripple-mark orientations of the abundant carbonate sand lenses suggest storm and/or tidal currents swept north–south or northeast–southwest across the open platform (Knight, *in preparation).*

The subtidal sediments indicate a prolonged period when relative sea-level rise was equal to or even greater than the rate of carbonate sediment production. This coincides with the highest stand of eustatic sea level in the Ordovician, as postulated by Vail *et al.* (1977).

The upper peritidal deposits of the upper megacycle consist of the microcrystalline dolostones and minor dolomitic shales and limestones of the Aguathuna Formation. They were deposited in peritidal settings interpreted by Pratt and James (1986) as a mosaic of shifting tidal flat islands accreting vertically and laterally on a very shallow shelf. Surfaces of subaerial exposure occur within the formation. An erosional disconformity is clearly present at the top of the formation in the south. It is not discernible over parts of the Great Northern Peninsula although it exists at Burnt Island, Pistolet Bay (Knight, 1986) and locally near Canada Bay (Knight, 1987). The regressive phase of this younger megacycle with its peritidal sediments culminating in subaerial exposure parallels that of the older cycle. The predominance of dolostones, the importance of cryptalgal laminites and shales, and the presence of all but the sparsest molluscan fauna together with silicified evaporites suggest that the environment was much more restricted and probably hypersaline than the overall environment of the Boat Harbour Formation.

The significance of the breaks within the formation is presently not resolved (Lane, 1984). On the Great Northern Peninsula, a probable break was suggested within the lower 30 m of the formation by Stouge (1982); a disconformity at the top of the formation in the same area is debated by different workers (Schuchert and Dunbar, 1934; Cumming, 1968; Knight, 1977; Pratt, 1979; Stouge, 1982; Lane, 1984). Preliminary faunal data relies upon sparse conodonts, graptolites and trilobites recovered from near-base and near the top of the formation. Development of different kinds of breccias (Lane, 1984) and locally developed stratigraphy and thickness variations within the formation near Daniels Harbour (Lane, 1984), indicate that a significant hiatus exists within the unit on the Great Northern Peninsula. This hiatus has recently been postulated to lie approximately 15 m below the top of the formation in this area and at the base of the formation near Port au Choix by Knight (*in preparation*, see also Knight and Boyce, 1984). Recent conodont studies in the Aguathuna Formation appear to confirm that this interval contains the hiatus, which separates a Canadian–Ibexian fauna from a fauna of Whiterock age (Kenna, 1985, personal communication, 1985). Whether this break corresponds to the erosional disconformity at Aguathuna, which separates the formation from the overlying Table Head limestone, is still unclear.

This rather complex geological picture of the end history of the St. George Group is probably the result of tectonic activity upon the platform in western Newfoundland. Minor northeast-trending faults that cut lower Catoche limestones near Hawkes Bay were active during deposition of the Aguathuna Formation (Knight and Boyce, 1984). Open spaces that developed along these faults are filled with dolomite-cemented sandstones resembling the sandy dolostones of the Aguathuna Formation. These are composed of dolomite and chert sand grains, the insoluble residue of Ordovician carbonate. Linear, northeast trending, rock matrix breccia units described by Lane (1984) at Daniel's Harbour may also have been controlled by similar faults. Additional evidence for fault-controlled topographic relief on the platform is provided by abrupt thickness changes in the Aguathuna Formation from Port au Choix to Daniel's Harbour. The loci of the change appears to be in the area just south of River of Ponds (Knight, 1985a). Since Aguathuna strata at Port au Choix compares to the uppermost beds of the Table Point section, it is reasonable to suggest that topographic relief or fault displacements of at least 45 m occurred upon the platform in this area. This record of tectonic activity probably records the first phases of Taconic orogenesis in western Newfoundland.

Large thickness variations in the overlying Table Head limestone, several beds of soft sediment deformation at Table Point and slump breccia near Port au Choix indicate that fault movements continued into the Middle Ordovician. Topographic relief upon the platform at this time was so substantial that it controlled deposition of the Table Head limestone during the final marine flooding of the platform during the early Middle Ordovician (Klappa *et al.*, 1980).

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APPENDIX

WATTS BIGHT FORMATION–(Type Section)

The strata are located in a two-part coastal section beginning 2.4 km south of Open Bay and culminating on Boat Head, 1 km north of the village of North Boat Harbour. The section is broken by a covered interval on the south side of Open Bay that conceals some minor faults. The beds in both parts of the section strike northeast and dip 4° to the southeast. The section is reached by foot from North Boat Harbour and by boat across Open Bay.

The upper boundary of the formation is placed at the top of a bed of mottled cryptalgal dolostone and below beds of buff-coloured, massive, mottled and laminated dolostone of the Boat Harbour Formation that break up northward into a coarse and fine rock matrix breccia of collapse or cavern origin. The lower boundary of the formation is conformable at Lower Cove, above a 1- to 4.2-m-thick sequence of bioturbated, thinly bedded dark grey, finely crystalline dolostone of the Petit Jardin Formation (Upper Cambrian).

UNIT NO	DESCRIPTION	UNIT THICKNESS IN M	CUMULATIVE THICKNESS IN M
14	DOLOSTONE: pale grey, finely crystalline, highly mottled, possibly cryptalgal mounds; chert composes 30% of bed; the unit disintegrates from south to north into a breccia, which cuts down 90 cm through the bed; basal 0.58 m is covered	2.30	89.45
13	DOLOSTONE: buff weathering, pale grey to dark grey, finely crystalline, largely cryptalgal mounds, which are strongly bioturbated, some digitate structure preserved; finely bioturbated dolostone draping around mounds; 4.5 m above the base of the unit, a 24 cm bed of finely laminated, yellow-weathering dolostone caps a mottled mounded bed	5.85	87.15
12	DOLOSTONE: dark grey, fine to medium crystalline, well-bedded, locally vuggy, bioturbated for much of the unit, some gastropods, some cryptalgal mounds 1.5 m from the top surrounded by and overlain by laminated and cross-laminated dolostone and cross-bedded dolarenite; chert nodules	5.25	81.30
11	DOLOSTONE: dark grey, fine to medium crystalline dolostone, beds 50- to 160-cm thick with large mounds composed of digitate and columnar stromatolites and/or irregular to laminoid fenestral porosity that mimics margins and tops of mounds; mounds are surrounded by bioturbated thinly bedded dolostone and locally by cross-bedded dolarenite; tops of some mounds are bioturbated and depressed with the depressions being filled by buff-weathering dolostone; cover for 1 m, 2.5 m from top; the top 1.5 m is mostly burrowed dolarenite with some small mounds and numerous cavities filled by geopetal dolomite muds	6.90	76.05
10	DOLOSTONE: black, fine to medium cyrstalline dolostone, bioturbated, rich in planispiral gastropods	1.80	69.15
9	COVERED INTERVAL: beach in cove	7.70	67.35
8	DOLOSTONE: dark grey to black, cherty, crystalline dolostone displaying very large mounds with digitate structure and cerebral weathered tops; vuggy and cavernous filled with brown geopetal dolomite mudstone; large basal mounds overlain by 1 m of thin-bedded and laminated, vuggy, yellow-weathering dolostone; the upper 2.8 m is thinly bedded and bioturbated with pale coloured mottling, and large mounds enclosed in the top 60 cm above a covered interval of 40 cm	5.00	59.65
7	DOLOSTONE: black to dark grey, fine to medium crystalline dolostone, thinly stratified, extensively bioturbated, some scour and fill, vuggy, chert nodules, pyritiferous, some gastropods; a 1.2-m covered interval 1.25 m from the base of the unit	8.25	54.65

UNIT NO	DESCRIPTION	UNIT THICKNESS IN M	CUMULATIVE THICKNESS IN M
6	DOLOSTONE: intercalated dark grey, thinly stratified, bioturbated dolostone and cross-bedded, lenticular and flaser-bedded, intraclastic and bioclastic dolarenite; scour and fill structures, imbricated intraclasts, and gastropods in dolarenites	3.65	46.35
5	DOLOSTONE: dark grey, fine to medium crystalline, bituminous, thinly stratified, some scours, bioturbated, some laminar fenestra toward base; the base is covered by the sea at the west side of Boat Head Here the section is continued north of Open Bay. The strata are linked by correlating a sequence, 7.8 m thick, of intercalated mounds, bioturbated dolostones and finely laminated dolostones rich in cavity porosity and geopetal muds on the southeast side of Open Bay with Unit 8 above. The sequence overlies a covered interval that conceals as much as 20 m of section suggesting there is perhaps 2 to 3 m of concealed section that would lie between Unit 5 on Boat Head and Unit 3, south of Open Bay	4.05	42.70
4	COVERED INTERVAL	2.5	38.65
3	DOLOSTONE: tan grey weathering, black, fine to medium crystalline dolostone, mostly well-bedded, bioturbated, characteristic light grey to white mottling; banks, nests and isolated large metre-sized, flat-topped mounds within the bioturbated beds; the mounds are surrounded by thin-bedded and lenticular-bedded dolostone, some rich in silicified straight cephalopods and high spired gastropods; internally the mounds show digitate structure, disrupted lamination and mottled texture (thrombolite?); mounds decrease in number upward; exposure incomplete in top 5.6 m	16.90	36.15
2	DOLOSTONE: dark grey to black, cherty, fine to medium crystalline; very large stromatolite mounds, silicified chert at base and within; internally, mounds consist of broad SH heads, and columnar and digitate growth forms or of abundant laminar fenestra that are lined by white dolospar, the fenestrae outline mound shape; other mounds have a coarse white tubular mottling that is subvertical and ramifies through the mounds; the mottled texture gives way upward to SH structures, which are capped by fine, crinkly lamination; other mounds are constructed of large, vuggy SH heads over-grown by large club-shaped heads; some stromatolite growth forms resemble conophyton (aberrant forms of Pratt and James, 1982) and inverted, vertically stacked cones; intermound areas are filled by thin bedding that is locally burrowed; coiled gastropods up to 5 cm diameter occur locally	10.65	19.25
1	DOLOSTONE: very thick beds of dark grey to black, fine to medium crystalline dolostone composed of large mound complexs of digitate, columnar, domal and conophyton-like stromatolites, fenestral-rich mounds and internally obscure mounds. Black to grey chert is abundant in mounds and forms layers that cap over tops of mounds; cavity spaces are abundant particularly in massive basal bed; some planispiral gastropods on top of some mounds; each mound bed (2- to 3.5-m thick) is capped by 0.18- to 0.20-m beds of light grey to black, planar to wavy laminated, microcrystalline dolostone	8.60	8.60

WATTS BIGHT FORMATION–(Reference Section)

These strata outcrop along the western shore of Isthmus Bay, Port au Port Peninsula. The sequence is continuous beginning at the high sea-cliffs, which form a conspicuous point where the coast changes direction from east–west to north–south some 1.4 km southwest of the gravel bar and continuing northward along the shore for approximately 0.5 km. The beds strike 050° and dip 40° to the northwest. All parts of the section are accessible and can be reached from numerous small trails that lead down from the main highway along the southern shore of the Port au Port Peninsula.

UNIT NO	DESCRIPTION	UNIT THICKNESS IN M	CUMULATIVE THICKNESS IN M
9	LIMESTONE: light grey to buff, medium- to thick-bedded complex of mounds and calcarenite; mounds are up to 1 m in diameter; two layers of columnar stromatolites surrounded and capped by calcarenite occur in the lower 4 m, a 2.1-m-thick thrombolite horizon occurs near the top; a thick calcarenite unit in the centre is fine to medium grained, cross-bedded, silica mottled and contains hard grounds; the lowermost beds are partially dolomitized	7.0	73.6
8	DOLOSTONE: the same massive yet thin-bedded lithology as below but in this part of the section the strata are wholly dolomitized; the basal 1 m is a zone of coarsely crystalline porous dolomite pods (replaced stromatolites) that are brecciated and overlain by a 1.5-m-thick dolarenite whose surface is irregular, cuts down section, and is capped by a chert conglomerate; the uppermost 2.5 m is a prominent, small cliff, which extends to the water line	8.0	66.6
	FAULT: displacement about 3 m in a small cove		
7	LIMESTONE AND DOLOSTONE: interbedded packages, 0.2- to 1.0-m-thick, of thin-bedded, bioturbated wackestone or thin-bedded bioturbated wackestone, grainstone and mudstone or medium- to thick-bedded, cross-laminated grainstone; any lithology may be partly to completely dolomitized to light grey, medium crystalline dolostone; minor chert; common gastropods	8.5	58.6
6	LIMESTONE: medium grey, thin-bedded grainstone and mudstone; burrows and gastropods, both of which are profuse on some bedding planes, and are replaced by medium crystalline, light grey dolomite; some beds partly dolomitized; minor cross-laminated grainstone beds; the interval between 4 and 6 m above the base is covered in a small cove	12.0	50.1
	Fossils: near base of the unit *Ophileta* sp. (?) *Lystospira* sp. near the top of the unit *Lecanospira* sp. (Flower, 1978, p. 217)		
5	LIMESTONE: at Green Head; a complex succession of fossiliferous thrombolite mounds and coarse-grained intermound calcarenite; partial dolomitization and silicification of the mounds result in a distinctive cerebral weathering pattern; these are described and illustrated by Pratt and James (1982, page 559, Figure 19)	12.0	38.1
	Fossils: gastropod *Euconia* sp. brachiopod *Finkelnburgia* sp. cephalopods *Ellesmeroceras* sp. *Ectenolites* sp. *Dakeoceras* sp. *Levisoceras* sp. *Bridgeoceras* sp. (Flower, 1978, p. 217).		

UNIT NO	DESCRIPTION	UNIT THICKNESS IN M	CUMULATIVE THICKNESS IN M
4	DOLOSTONE: dark to medium grey, medium- to thick-bedded, burrow-mottled, medium crystalline; some zones of vuggy porosity; burrows and gastropods conspicuous; minor white to red chert nodules; grades westward along strike into limestone (wackestone) with dolomitized burrows; forms a prominent small cliff, which can only be scaled at lowest tide	10.1	26.1
3	LIMESTONE: digitate stromatolites and white to light grey dolomite; each stromatolite is layer capped by laminated mudstone and black to red, ropey to nodular chert	2.0	16.0
2	DOLOSTONE: a prominent ledge of dark to medium grey dolostone as in Unit 1 with a thin lime mudstone unit at 3 m; the upper metre is a series of cryptalgal dololaminites and small stromatolites with chert; the very top is a 5 cm lens of silicified conglomerate	5.2	14.0
1	DOLOSTONE: medium to dark grey, mottled to poorly laminated; flat-pebble conglomerate at base; calcite vugs in lower part; at 5 m, irregular black chert replaces stromatolites, at 7 m there is a consistent red and black chert layer; upper 1.2 m is a dololaminite with prism cracks and teepee structures; forms a small cliff and headland at the southern most point of Isthmus Bay	8.8	8.8

BOAT HARBOUR FORMATION–(Type Section)

The type section begins on the western shore of Boat Harbour and continues 3.7 km northeastward along the low rocky shoreline of the bay to a line of cliffs. The section is readily accessible from the highway between Cooks Harbour and North Boat Harbour. The beds strike northeast and dip 3° to 5° to the southeast. Here, the formation is conformably overlain by 21 m of limestone and 32 m of diagenetic dolostone belonging to the Catoche Formation. The base of the formation rests conformably upon strata of the Watts Bight Formation type section.

UNIT NO	DESCRIPTION	UNIT THICKNESS IN M	CUMULATIVE THICKNESS IN M
13	LIMESTONE, DOLOMITIC LIMESTONE AND DOLOSTONE: intraclastic packstones and grainstones, bioturbated bioclastic and peloidal wackestones with upward decrease of skeletal particles, and argillaceous lime mudstones with dolomitic laminae and dolostones arranged in six upward shoaling sequences of 0.90 to 6.4 m thickness; scours and possibly karsted surfaces, lensoid bedding, ripple cross-lamination, imbricated intraclastic rudstone lenses, some small SH stromatolite heads and skeletal cone-shaped mounds in basal grainy beds; bioturbated thin stratification to flaser and wavy thin bedding in wackestone; lamination, cross-lamination, scour and fill, thin grainstone layers, shale flaser, fissure cracks and mud-cracks in mudstones and dolostones; a 30-cm thrombolitic boundstone bed occurs in the third sequence 4 m from the base of the unit, it is surrounded by thin-bedded bioclastic grainstone–packstone; beds are very fossiliferous; lime mudstone and dolostone form a 4.4-m interval at the top of the upper sequence; unit forms the Barbace Cove Member	17.10	120.70
12	PEBBLY DOLOSTONE: pale grey, finely crystalline dolostone with a basal layer 2-cm thick of sparce to concentrated, 1 cm pebbles of white megaquartz and grey, black and banded chert; a very irregular solution pitted surface capped by 1/2 cm of grey shale 8 to 17 cm above the pebble layer; pebbles are also scattered in the overlying 24 to 35-cm dolostone bed that appears to be	0.40	103.60

UNIT NO	DESCRIPTION	UNIT THICKNESS IN M	CUMULATIVE THICKNESS IN M
	bioturbated and possess crinkly lamination at the top; known as the Boat Harbour 'pebble bed'		
11	LIMESTONE AND DOLOSTONE: rubbly weathering, dark grey, bioturbated, bioclastic wackestone and packstone with minor lime mudstone and some mottled boundstone mounds locally; a resistant ledge of skeletal packstone and grainstone 5 m from base; gastropods and brachiopods common; upper 80 to 90 cm is dolomitized beneath Boat Harbour 'pebble bed', white megaquartz nodules and streaky porosity with geopetal dolomite and sparry cement immediately below pebble bed	8.40	103.20
10	COVERED INTERVAL: beach with a 50 cm bed of thinly bedded and planar-laminated lime mudstone at top of interval on the northeast side of the beach	5.90	98.80
9	LIMESTONE: beds of wackestone and intercalated boundstone; a 70-cm bed of stromatolitic boundstone and oolitic grainstone 1.15 m from the base, and large stromatolitic and thrombolitic mounds in the upper 2 m; wackestone is thinly stratified, bioturbated, cherty, rich in gastropods and a few trilobites; the stromatolites are low, broad mounds of LLH and SH structures with intraclastic and skeletal packstone, oolitic grainstone fill in intermound areas and surround the mounds; chert and large number of gastropods and cephalopods near mounds	4.05	88.90
8	LIMESTONE AND MINOR DOLOSTONE: boundstones intercalated with lime mudstone, dolomitic lime mudstone, dolostone and some wackestone in three couplets 3.7, 2.25 and 0.30 m in thickness; dark grey to black boundstones in the lower two couplets consist of large thrombolites mounds with steep overhanging margins and intraclastic rudstone intermound fills, chert, fluorite; locally mounds pass into bioturbated gastropod-rich wackestone; top boundstone bed is of cryptalgal laminite overlain by broad heads of LLH structures; interbedded lime mudstone and dolostone are planar- to wavy-thin bedded, laminated, sparsely bioturbated to unbioturbated, with shallow scour and fill structures	6.25	84.85
7	LIMESTONE: grey, well-bedded, thinly stratified wackestone with gastropods and some lamination; 70-cm bed of cryptalgal mounds overlain by laminated and flaser-bedded lime mudstone and rare trails 3.5 m from top of unit; 60 cm covered interval 1.95 m from base	9.10	78.60
6	LIMESTONE: boundstone and wackestone; boundstone mounds of SH and LLH structures with much silicification in the lower 1.96 m, skeletal-rich, vuggy, thrombolitic mounds in top 65 cm; middle bed of intensely bioturbated wackestone with gastropods and cephalopods; basal mound beds replaced in places by epigenetic dolostone	3.70	69.50
5	LIMESTONE-DOLOSTONE: wackestone, packstone, mudstone and minor boundstone; lime wackestones–mudstone units are thinly bedded, bioturbated with dolomitic mottles, lenses of mudstone and intraclastic packstone, rich in gastropods, cephalopods, trilobites; 60 cm covered interval at base; units traced across fault zone and minor covered interval; limestones replaced by epigenetic dolostone near fault	11.85	65.80
4	LIMESTONE: dark grey, bioturbated, thinly bedded, bioclastic wackestone beds 0.8- to 3.3-m thick with lenses of intraclastic–bioclastic grainstone, several boundstone beds in some cases associated with intraclastic grainstone and rudstone fringes and intermound deposits, and beds of laminated and thinly	14.85	53.95

UNIT NO	DESCRIPTION	UNIT THICKNESS IN M	CUMULATIVE THICKNESS IN M
	bedded, flaser-bedded sparsely bioturbated, lime mudstone, and rare dolostone; boundstones are cherty, and include thrombolites, and SH and LLH stromatolite; in broad mounds; beds generally fossiliferous; 35-cm covered interval 5.5 m above base		
3	LIMESTONE AND EPIGENETIC DOLOSTONE: dark grey to blue-grey lime mudstone and wackestone; wackestone is bioturbated, thinly bedded, with some gastropods, lime mudstone is smoothly undulose to planar laminated to thin bedded, some mud-cracks, surface trails; individual limestone beds are replaced along strike by epigenetic dolostone rich in secondary porosity and white saddle dolomite	19.05	39.10
2	COVERED INTERVAL: Boat Harbour Bay; some outcrops of vuggy, bioturbated, dark grey, epigenetic dolostone and flaser- and lenticular-bedded and laminated, buff and pale grey microcrystalline dolostone	14.65	20.05
1	DOLOSTONE BRECCIA: buff weathering, finely crystalline dolostone blocks and rubble set in a dark dolomite matrix in lower levels and cemented by white saddle dolomite for top 2 m; fragments are structureless or show thin stratification, lamination and mottled fabrics; chert common; base is irregular with breccia passing laterally into coherent beds; crude internal stratigraphy to rubble mass	5.40	5.40

BOAT HARBOUR FORMATION–(Reference Section)

The section lies along the western shore of Isthmus Bay, Port au Port Peninsula and extends from the southern gravel bar southward along the coast for roughly 0.6 km. Outcrop is continuous but broken by a fault near the base. The beds strike 050° and dip 40° to the northwest. The section is easily accessible from numerous trails that lead down to the shoreline from the main highway along the south side of the peninsula.

The base of the formation is placed at the contact between a lower series of light grey stromatolite or thrombolite mounds and cross-bedded calcarenites and an upper series of distinct, very thin-bedded limestone and minor dolostones. This contact is exposed in a broad cove often used to store small boats. The top of the formation is placed at the top of a series of numerous dololaminites and thin-bedded limestones, with the beds above being only limestone. Approximately 13.5 m of Catoche Formation is well exposed above the upper contact, with a further 148 m only intermittently visible in scattered outcrops northward along the western edge of the pebble bar known as 'The Gravels'.

UNIT NO	DESCRIPTION	UNIT THICKNESS IN M	CUMULATIVE THICKNESS IN M
11	LIMESTONE AND DOLOLAMINITE: similar to Unit 10 but twice as many dololaminite units per unit thickness; between 4 m and 7 m there are several distinctive, brown-weathering, argillaceous dololaminites; thrombolite boundstones near the base contain stick-shaped sponges, the top of this unit and formation is placed at the uppermost dololaminite	12.0	155.9
10	LIMESTONE AND DOLOLAMINITE: packages of thin-bedded, rubbly to nodular, commonly fossiliferous limestone of various lithologies alternating with mud-cracked dololaminite; limestone is distinctly more fossiliferous than that in the lower units, mostly coarse-grained grainstone to rudstone, bioclastic and/or oolitic with numerous intraclasts and clasts of mudstone; wackestone units commonly exhibit dolomitized burrows, small stromatolites and	12.8	143.9

UNIT NO	DESCRIPTION	UNIT THICKNESS IN M	CUMULATIVE THICKNESS IN M
	thrombolite mounds; at the top of the unit is a stromatolite horizon with oolitic, bioclastic and intraclastic sediment, a hardground surface and mud-cracks; at 3 m there is a small fault with 0.2 m displacement		
9	LIMESTONE AND DOLOSTONE: thin- to medium-bedded limestone and dolomitized limestone alternating with dololaminite; the limestones are similar to those in Unit 7, mainly thin-bedded grainstone and wackestone with dolomitized burrows, generally bioclastic and alternating with beds of thrombolite mounds, these lithologies are dolomitized in the upper 4 m; the dololaminite is cryptalgal, current-laminated, contains mud-cracks, grainstone lenses and small SH stromatolites; Units 9 to 11 comprise the Barbace Cove Member	12.8	131.8
8	DOLOSTONE: medium to coarsely crystalline dolomite replacing limestone lithologies described below, brecciation and numerous chert layers, dolostones vary from dololaminite to burrowed and bioturbated; lithologies at 3 m and 5 m are limestone thrombolites and stromatolites; the base of the unit is marked by mounds (stromatolites?) replaced by coarsely crystalline vuggy dolomite; the upper 5 m exhibits brecciation, coarsely crystalline dolomite replacement, and vugs lined with laminated dolomite; red and black chert layers and nodules are common; the top of the unit is a chert and dolomite-pebble conglomerate; the whole upper sequence is interpreted as a zone of paleo-exposure correlated with the Boat Harbour 'pebble bed'	10.5	119.3
7	LIMESTONE AND DOLOLAMINITE: (repeatedly) interbedded limestones of various lithologies and dololaminites, commonly with prism cracks; the limestones are either; 1) thinly interbedded grainstones, wackestones and mudstones, which are irregular to nodular bedded and may be burrowed, bioturbated, bioclastic, intraclastic or rippled; 2) thin- to medium-bedded bioclastic to intraclastic to ooid grainstones that are normal to herringbone cross-laminated, rippled and display omission surfaces; and 3) medium-bedded stromatolite to thrombolite boundstones; light grey dolomite commonly replaces burrows and gastropods and a few thin beds are wholly dolomitized; scattered but minor silicification; ripples on adjacent beds have markedly different orientations; distinctive horizons occur at: 10 m, a series of thrombolites and grainstones with scalloped hardground erosion surfaces; at 15.5 m, hardgrounds on a thrombolite horizon; at 25 m, deep and distinctive prism cracks in dololaminite; at 29 and 32 m, ooid grainstones with hardgrounds; at 45 m, a series of distinctive digitate mounds with flask-shaped intermound sediment fills; above 47 m limestones are almost all dolomitized but some relic fabrics are recognizable	57.0	108.8
6	LIMESTONE: a conspicuous unit of interbedded stromatolites, thrombolites, and grainstone; stromatolites are mostly broad, low relief LLH and SH to columnar forms from 0.1 to 2 m in diameter with less than 1 m of relief; stacked mounds form structures 4 to 5 m in diameter and 2 m in height, thrombolites have similar characteristics; sediments range from mud-cracked, laminated mudstone, which caps mounds to burrowed wackestone between cross-laminated, coarse-grained intraclastic,skeletal and ooid grainstone on top of and between structures; gastropods and skeletal hash are conspicuous	9.0	51.8
	FAULT—strikes approximately north—south, the western limb is upthrown, likely minor displacement		

UNIT NO	DESCRIPTION	UNIT THICKNESS IN M	CUMULATIVE THICKNESS IN M
5	DOLOSTONE: medium grey, thinly bedded; similar fabrics to the limestones in lower units, burrowed and bioturbated; at 2.5 m is an omission surface with silica-lined vugs; at 9 m there are several silicified horizons; at 8 m there is a white-weathering conglomerate horizon	12.4	42.8
4	DOLOSTONE: interbedded buff-weathering, planar dololaminite with desiccation cracks and flat-pebble conglomerate; grey- to light grey-dolostone that is identical to limestone in Unit 3 but with relic fabrics	4.0	30.4
3	LIMESTONE AND DOLOSTONE: thinly interbedded lime mudstone, wackestone, grainstone and dolomitized units of the same with one dololaminite containing prolate stromatolites at 2 m above the base; limestone is lenticular, bioclastic, burrowed, cross-laminated, rippled, nodular, bioturbated	8.4	26.4
2	LIMESTONE AND DOLOSTONE: thinly interbedded dolostone and lime grainstone, similar to Unit 1 but more grainstone; cross-laminated, scour and fill structures, bioturbation; at 2 m there is a 1-m-thick zone of vuggy, moldic dolostone	9.0	18.0
1	LIMESTONE AND DOLOSTONE: exposed in a broad cove commonly used to store small boats, iron spikes are driven into the rock at several places; distinguished from other units by thin to very thin-bedding and abundant fossils; limestone is irregular to nodular, thin to very thin-bedded mudstone to wackestone with anastomosing burrows and macrofossils replaced by light-grey to buff-weathering, medium crystalline dolomite; parted in places with layers of buff-weathering argillaceous dolomite, mud-cracked layers, thin-bedded layers and lenses of grainstone to rudstone, rich in fossil fragments but also containing intraclasts and flat pebbles, and exhibiting hardgrounds and sinuous to rhomboid ripples (orientation 050°–230°); conspicuous gastropods, cephalopods and brachiopods; dolostone is light to medium grey dolomitized limestone with relic fabric or dololaminites in beds up to 0.5-m-thick exhibiting cross-lamination	9.0	9.0

CATOCHE FORMATION–(Type Section)

The type section hugs the low rock ledges and shallow coves of the shoreline of Bustard Cove from Hunters Point southward to the east shore of Back Arm where the top of the formation occurs 0.6 km north of Port au Choix. The beds strike east to southeast and dip between 2° and 5° to the south. The base of the section is reached by foot from a gravel road, west through Eddies Cove West. The section along Bustard Cove is accessible from the old Northern Peninsula highway road between Port au Choix and Eddies Cove West. A gravel track to the shore leaves the old highway 8.5 km from Port au Choix. The shore of Back Arm can be reached on foot from the old highway and from wharf facilities at Port au Choix.

The formation is conformable upon a well exposed section of the Boat Harbour Formation, which forms the rocks that occur around a broad sweeping bay north of Hunters Point known as Old Man Cove. The Catoche Formation at Back Arm is overlain apparently conformably by 5 m of buff-weathering, microcrystalline dolostone of the Aguathuna Formation, which sit conformably beneath cyclic limestones of the Middle Ordovician Table Point Formation.

UNIT NO	DESCRIPTION	UNIT THICKNESS IN M	CUMULATIVE THICKNESS IN M
14	DOLOSTONE: thickly bedded, tan-grey weathering, dark- to light-grey, fine to medium crystalline dolostone with abundant porosity and much white sparry dolomite; pseudobreccia (Cumming, 1968) occurs in some beds; some pods	34.10	160.30

UNIT NO	DESCRIPTION	UNIT THICKNESS IN M	CUMULATIVE THICKNESS IN M
	of limestone enclosed in the dolostone near the top; beds preserve some depositional fabrics including bioturbation and gastropods; beds are generally composed of fine, tight dolostone, preserving discontinuous thin-bedding and sparce mottling at base and top with a middle zone rich in porosity, saddle dolomite and rafts of strongly mottled, dark grey, fine to medium crystalline dolostone: 1 m, 1.25 m and 1.5 m covered intervals at 9 m, 15 m, 21.5 m from the base which is covered		
13	COVERED INTERVAL: beach and glacial drift	32.00	126.20
12	LIMESTONE: dark grey, burrow mottled, lime wackestone–mudstone with lime mudstone flaser and bioclastic, peloid, and intraclastic–bioclastic packstone and grainstone lenses and layers that may have ripple marked tops; extremely fossiliferous in some layers–gastropods, cephalopods, trilobites, receptaculitids, eocrinoids and brachiopods; 1.1 m covered interval 1.8 m from base, 0.8 m covered interval 3 m from top	8.25	94.20
11	LIMESTONE: thrombolitic boundstone mounds of large size, surrounded by well cemented grainstone; large straight cephalopods, large and small trilobites, plani- and high-spired gastropods, sponges, receptaculitids; possible stromatolite near base of mounds; mounds decrease in size to south	1.00	85.95
10	LIMESTONE: dominantly composed of well-bedded, intensely and moderately bioturbated wackestone–packstone with grainstone layers and lenses; fossils are common; grainstones have scoured to planar bases, cross-lamination and ripple-marked tops, some starved ripples; small centimetre-high and diameter boundstone mounds generally surrounded by grainstones, 10.5 m, 17 m, and 28 m from base of unit; fossils include trilobites, gastropods, cephalopods, brachiopods; chert nodules at 10.5 m; prominent intraclastic grainstone at 11.85 m from base; 40-cm, 35-cm, 55-cm, and 70-cm covered intervals at base, 3.6 m and 11.35 m and 26.5 m above base; limestone 5 m from top is replaced by epigenetic dolostone	29.75	84.95
9	LIMESTONE: rubbly weathering, thrombolitic boundstone mounds, metre-sized, irregular to spherical in shape; gastropods, cephalopods and trilobites	0.60	55.20
8	LIMESTONE: dark grey, wackestone–packstone interspersed with scour-based, skeletal, intraclastic grainstone and some intraclastic rudstone; fossiliferous with brachiopods, high-spired and planispiral gastropods, cephalopods, trilobites; wackestones that intensely bioturbated for basal 55 cm; 1.8 m and 0.9 m covered interval 0.55 m and 2.9 m from base	10.90	54.60
7	LIMESTONE: thrombolitic–sponge boundstone mounds in north–south oriented linear banks 6-m wide and up to 75-m long; rich in large bodied shelly fauna; the mounds are separated by thinly-bedded skeletal wackestone and some crossbedded grainstone with straight ripple marks locally	0.30	43.70
6	LIMESTONE: wackestone–packstone with lenses and layers of grainstone; well bedded, bioturbated, dolomitized burrows, large broad scours, fossiliferous; some wackestone beds with uneven thin stratification, dolomite drapes, few fossils; grainstones are scour based, cross-laminated to crudely planar-stratified, ripple-marked tops, starved ripple marks, rich in intraclasts and bioclasts; some minor, centimetre-sized boundstone mounds; 3.1-m covered interval 1 m above the base, covered interval 1.0-m thick (gravel beach, storage area for lobster pots) 5.2 m from top; minor covered intervals at 4.5 and 6.7 m from base	19.70	43.40

UNIT NO	DESCRIPTION	UNIT THICKNESS IN M	CUMULATIVE THICKNESS IN M
5	LIMESTONE: interbedded lime mudstone, wackestone, grainstone–packstone with minor boundstone; bedded, bioturbated wackestone with ripple-marked, scour-based lenses of packstone–grainstone at base overlain by lime mudstone–wackestone displaying smooth, wavy, thin bedding, flaser and low density bioturbation interbedded with scour-based, intraclastic–skeletal grainstone–rudstone; grainy beds, 10- to 15-cm-thick have rippled tops, cross-bedding, planar stratification, imbricated intraclasts, lime mudstone drapes, locally abundant gastropods and other fossils; boundstone mounds 35-cm high surrounded by skeletal packstones that pass eastward into wackestone and are capped by grainstone beds, which occur 35 cm to 50 cm from top; mud-cracks in 70-cm bed of flaser-bedded shaly lime mudstone 5.35 m from base	6.70	23.70
4	LIMESTONE: wackestone with packstone–grainstone–rudstone beds and lenses and some boundstone mounds; the wackestones are unevenly thinly stratified, bioturbated with dolomitized burrows and fossiliferous including gastropods, cephalopods, brachiopods, trilobites and crinoids; the grainy beds and lenses composed of intraclasts and bioclasts are scour-based, ripple-marked including starved ripples, intraclasts of red lime mudstone; 30- to 40-cm-thick intraclastic rudstone bed with channel scour base, edgewise orientation of intraclasts, large fossil fragments and wackestone drapes, 2.25 m from base; basal 20 cm of unit consists of thrombolitic boundstone mounds surrounded by bedded bioclastic wackestone	7.20	17.00
3	LIMESTONE: dark grey wackestone–packstone, well bedded, bioturbated, fossiliferous especially in 1 to 3 cm packstone layers that also enclose intraclasts and coated grains; rich in gastropods and cephalopods; 1.5 m covered interval at top and also 2-m thick, 2 m from base	6.70	9.80
2	LIMESTONE: dark-grey, thrombolitic boundstone in large mounds rich in skeletal remains including sponges, trilobites, eocrinoids, gastropods and cephalopods; mounds end abruptly at the south end of Hunters Point passing into bedded wackestone with abundant opercula	1.65	3.10
1	LIMESTONE: wackestone–packstone with a 20-cm layer of laminated dolomitic lime mudstone at 40 cm; wackstone–packstone is dark grey, massive, rubbly weathering to thinly stratified, fossiliferous with trilobites, ostracods, gastropods and cephalopods; Unit 1 sits conformably upon a mud-cracked, laminated, dolomitic, shaly lime mudstone unit that forms the top of the Boat Harbour Formation	1.45	1.45

CATOCHE FORMATION–(Reference Section)

The strata are well exposed along the rocky shoreline of the western side of the Port au Choix Peninsula from Catoche Island south to Laignet Point. The section then continues south of the mouth of the Port au Choix cove, south to Blanche Point. The beds strike 120° and dip 4° to 10° to the south. The section is readily accessible by foot from gravel roads that lead out onto the Port au Choix and Pointe Riche peninsulas from Port au Choix.

The top of the formation is concealed beneath a long covered interval south of Blanche Point. A number of northeastward and southeastward-striking faults dissect the lower strata of the section.

UNIT NO	DESCRIPTION	UNIT THICKNESS IN M	CUMULATIVE THICKNESS IN M
18	DOLOSTONE: dark grey to grey, fine to medium crystalline dolostone, thickly bedded, massive weathering, bituminous, vuggy, with beds of 'pseudobreccia'; abundant secondary porosity lined by white saddle dolomite; some beds contain ghosts of gastropods and cephalopods, burrow mottling	38.85	152.50
17	COVERED INTERVAL: mouth of Port au Choix cove; locally small outcrops of limestones composed of bioclastic wackstone with *Receptaculites*	10.0	113.65
16	LIMESTONE: wackstone–packstone with grainstone lenses; bioturbated, dolomitized burrows, some beds extensively dolomitized; grainy lenses composed of intraclasts, bioclasts, coated grains, peloids; fossils include eocrinoids, *Receptaculites*, trilobites, gastropods and large cephalopods; 14.8 m from top of unit there is a covered interval of 1 m in narrow channel between mainland and island at Laignet Point	23.50	103.65
15	LIMESTONE: boundstone and wackstone; rubbly weathering, dark grey limestone composed of very large thrombolite mounds with large sponges, cephalopods, gastropods and other fossils and of calcite-cemented to dolomitized grainstone in intermound areas and fringing mounds; grainstones grade laterally into bioturbated, bioclastic wackestone–packstone; massive, mottled, dolomitic wackestone bed 35 cm thick drapes over the mound bed	2.15	80.15
14	LIMESTONE: wackestone–packstone with grainstone lenses; well-bedded, dark grey, rubbly weathering, bioturbated, thinly stratified, bioclastic–peloidal wackestone–packstone; grainstone lenses are mostly ripple marked, cross-laminated with some hardgrounds; boundstone mounds, 5 to 20 cm high surrounded by grainstone 2.5 m from top; small centimetre-high mounds in some beds; 65 cm bed of massive, dolomite mottled, dolomitic lime wackestone 1.25 m from base; 1.25 m covered interval 4.2 m from base	15.90	78.00
13	LIMESTONE: boundstone–wackestone–packstone; 1 to 2.2 m diameter, 0.20 to 0.40 m high, scattered, irregular shaped, sponge–thrombolite mounds surrounded by thin-bedded wackestone–packstone	0.30	62.10
12	LIMESTONE: wackestone–packstone and grainstone lenses in elongate sinuous scours; main lithology is thinly bedded, bioclastic burrow, mottled with gastropods	5.56	61.70
11	LIMESTONE: thrombolite–sponge boundstone mounds rich in large cephalopods, gastropods and trilobites; grainstone accumulated between small mounds that make up large mound banks; banks are separated by 20-m-wide channels filled by interbedded, thinly bedded, wackestone, packstone and grainstone	1.30	56.07
10	LIMESTONE: dark grey, wackestone–packstone and grainstone layers and lenses; wackestone–packstone is thinly stratified and bioturbated; irregular cross-cutting surface 65 cm from top overlain by several grainstone beds; some grainstones are ripple marked, and formed hardgrounds	6.10	54.75
9	LIMESTONE: boundstone overlain by 10 to 20 cm of dolomite-mottled, light grey wackestone; thrombolitic boundstones mounds are oriented 185°, fringed by grainstone that passes into highly bioturbated thinly bedded wackestone–packstone–grainstone rich in gastropods; top of mounds may be locally eroded	0.65	54.75

UNIT NO	DESCRIPTION	UNIT THICKNESS IN M	CUMULATIVE THICKNESS IN M
8	LIMESTONE AND DOLOMITIC LIMESTONE: sequences 2.5 to 10.85-m thick of bioturbated, uneven to evenly thin-bedded dark-grey wackestone–packstone with ripple-marked and planar-stratified grainstone layers and lenses; fossiliferous, including trilobites, eocrinoids, cephalopods, gastropods and brachiopods; these are intercalated with 17- to 30-cm beds of dolomite-mottled lime mudstone–wackestone or limestone mottled dolostone at 10.85 m, 18.3 m and 21.65 m, the beds are massive, or smooth thinly bedded and lenticular bedded with some grainstone lenses containing the large trilobite, *Isoteloides;* small 5- to 20-cm-diameter thrombolite boundstone mounds in 20-cm bed below the top dolomitic wackestone bed, mounds flanked by bioclastic packstone	25.00	48.00
7	LIMESTONE: lime mudstone–wackestone with grainstone layers and lenses, and wackestone–packstone; fine mudrock is unevenly to wavy thin-bedded, shaly, cross-laminated with gutter casts; 23 cm, cross-laminated, ripple-marked grainstone bed and mudstone flaser and lenses with the large trilobite *Isoteloides peri* and graptolites 30 cm from the top beneath shaly lime mudstone; wackestone–packstone beds bioturbated with grainstone lenses, abundant gastropods and ripple marks	5.25	23.00
6	LIMESTONE: wackestone–packstone, bioturbated, thinly bedded; east- to southeast trending fault cuts base of unit in a zone several metres wide on the south side of Catoche Island, downthrow to the south, amount of displacement and loss of section unknown; section continues downward on Catoche Island	4.70	17.75
5	LIMESTONE AND DOLOMITIC LIMESTONE: interbedded dolomitic wackestone–packstone, lime mudstone, grainstone and rudstone; lime mudstone and wackestone–packstone beds are lumpy to wavy thin-bedded, burrowed, fossiliferous (mostly gastropods) with laminated and cross-laminated, very fine grained grainstone lenses and intraclastic-bioclastic grainstone lenses; rudstone sheets, 10- to 30-cm thick, composed of reddish-grey, discoid intraclasts of lime mudstone with sparry cement	6.25	13.05
4	LIMESTONE: rudstone, composed of imbricated, reddened, discoid lime mudstone intraclasts; spar-cemented, cross-bedded, thin wackestone drapes at intervals, planar top, erosive base	0.65	6.80
3	LIMESTONE: bioturbated, well bedded wackestone–packstone and grainstone lenses; intraclastic rudstone beds interbedded with burrowed, wavy thin-bedded and flaser bedded dolomitic lime mudstone in top 50 cm; base covered at sea level; Units 3 to 5 are separated from Units 1 and 2 on the north side of the island by a north trending fault that downthrows to the east; thickness of section missing is probably less than 2 m	4.10	6.15
2	LIMESTONE: boundstone mounds rich in sponges, trilobites, gastropods, cephalopods, eocrinoids associated with spar-cemented grainstone	0.55	2.05
1	LIMESTONE: wackestone–packstone, bioturbated, abundant fossils, small boundstone mounds 30 cm from base; conformably overlies mud-cracked, laminated dolomitic lime mudstone unit forming top of the Boat Harbour Formation	1.50	1.50

AGUATHUNA FORMATION–(Type Section)

This shoreline section lies north of Table Point forming a broad cove south of the river, which flows into Freshwater Cove (Figure 3c). The main Northern Peninsula highway runs parallel to and some 200 to 300 m east of the shoreline in this vicinity and all parts of the section are easily accessible from the road. The sequence is exposed as a series of irregular cliffs some 8 to 10 m high separated by covered intervals and as a wide continuously exposed intertidal platform; the two are separated by a wide boulder or wrack beach and berm. The section itself is in the intertidal zone and so can be examined, only at low tide during calm weather. Strata strike 155° to 170° and dip 9° to 14° to the south. The formation is overlain by intercalated limestone and dolomitic limestone of the Middle Ordovician Table Point Formation. The section and location of the overlying Table Point Formation is figured in Klappa *et al.* (1980, pages 1017-1019). The Aguathuna Formation is underlain by some 25 m of thick bedded, rubbly weathering, bioturbated, fossiliferous limestone and massive weathering, diagenetic and epigenetic dolostone of the Catoche Formation. Dolostone laterally replaces limestone that contains brachiopods, trilobites and gastropods; dolostone locally highly porous and rich in white saddle dolomite.

UNIT NO	DESCRIPTION	UNIT THICKNESS IN M	CUMULATIVE THICKNESS IN M
10	DOLOSTONE: light grey to tan-weathering, blue grey, thick-bedded bioturbated medium crystalline dolostone; thin dololaminite; top placed at uppermost, 0.5 m thick, slightly calcareous, mud-cracked cryptalgal dolostone, which lies on an irregular, buckled surface penetrated by burrows; trilobites: *Acidiphorus pseudobathyurus* (R.A. Fortey, personal communication, 1984), 2 m from top, *Bathyurus perplexus* (W.D. Boyce, personal communication, 1984) occurs just below top	0.80	63.10
9	DOLOSTONE: light grey to tan-weathering, siliceous, medium to microcrystalline, light grey dolostone, thick to medium bedded; planar laminated to bioturbated, massive alternating with thin-bedded, argillaceous, fissile dolostone; 0.5- to 1.0-cm-thick lenses and sheets of fine- to coarse-grained quartz sand and chert pebbles at top; dark grey weathering, argillaceous dolostone at base	9.55	57.30
8	DOLOSTONE: microcrystalline, grey to tan-weathering, light grey; alternating laminated massive and burrow mottled, thin- to thick-bedded units; nodules of black or white chert at 2 m from base and at top; thin beds of fine- to medium-crystalline, vuggy dolostone	5.25	47.75
7	DOLOSTONE: tan-weathering, light grey, massive, thick- to thin-bedded, burrow-mottled microcrystalline	4.8	42.5
6	DOLOSTONE: dark grey and tan-weathering, light grey, microcrystalline, thin to medium bedded, massive bioturbated and planar laminated beds with scour and fill structures, mud-cracks and flat pebble conglomerate; alternating with green-grey, recessively-weathering argillaceous dolostone or dolomitic shale; top and bottom of unit marked by argillaceous units 0.5 m in thickness	6.0	37.7
5	DOLOSTONE: grey weathering, fine- to microcrystalline, thick-bedded; most of bed is LLH-C stromatolites, overlain by burrow–mottled dolostone with chert on bedding planes; lower part of unit is a recessively weathering breccia, composed of angular, poorly sorted dolostone clasts up to 30 cm in size in smaller dolomite and coarse angular fragments of white chert in green dolomitic shale	2.1	31.7
4	DOLOSTONE: buff to tan-weathering, light to dark grey, medium to microcrystalline, commonly siliceous; alternating beds of laminated and bioturbated, massive dolostone, burrows and macrofossils on bedding planes; breccia 5 m from base, 1-m thick, clasts of burrowed and laminated dolostone and white chert in a fine crystalline dolomite matrix, covered by grey shale, which forms matrix in upper part	23.1	29.6

UNIT NO	DESCRIPTION	UNIT THICKNESS IN M	CUMULATIVE THICKNESS IN M
3	DOLOSTONE: grey-weathering, microcrystalline, massive to micro-laminated, dark grey, argillaceous partings	1.2	6.5
2	DOLOSTONE: buff-weathering, 0.2- to 1-m-thick beds of fine to medium crystalline, bioturbated dolostone with abundant *Chondrites* and finely crystalline, crinkly laminated to micro-laminated to cross-laminated, siliceous dolostone with rare burrows; white chert blebs	4.3	5.3
1	DOLOSTONE: buff-weathering, dark grey, microcrystalline, laminated, with minor trace fossils, planispiral gastropods, undetermined trilobites and the graptolites: *Didymograptus (Extensograptus) extensus, Didymograptus (Extensograptus)* ex. gr. *nitidus* (H. Williams, personal communication, 1984)	1.0	1.0

AGUATHUNA FORMATION–(Reference Section)

This section forms the southwestern shore of East Bay, Port au Port Peninsula, north of 'The Gravels' isthmus (Figure 3d). The rocks are easily accessible just off the main highway after crossing the isthmus and are exposed as a series of 2 to 4-m-high sea cliffs footed by a narrow irregular intertidal platform. The section is most easily studied during low tide, calm weather and when the wind blows from the south because the best outcrops are in the intertidal zone. Normal faults break the middle part of the section but offset is never more than a few metres. The beds strike 040° and dip 30° to the northwest. The section is overlain by 40 m of fenestral and fossiliferous limestones of the Middle Ordovician Table Point Formation above an irregular basal contact.

UNIT NO	DESCRIPTION	UNIT THICKNESS IN M	CUMULATIVE THICKNESS IN M
11	DOLOSTONE: tan-weathering, massive, thin, stylobedded, burrowed dolostone grades into thin 0.5-m-thick, fossiliferous, burrowed limestone at base	5.1	67.5
10	DOLOSTONE: massive, thick-bedded, tan-weathering dolostone; planar to irregular laminations, bioturbation and burrows, small stromatolites; thin limestone at top and bottom; two conspicous irregular dissolution horizons 1 and 2 m below the top, basal limestone that is lenticular, stromatolitic and contains abundant chert nodules and masses	6.0	62.4
9	DOLOLAMINITE AND ARGILLACEOUS DOLOSTONE: tan-weathering, planar laminated, microcrystalline dolostone in beds up to 1 m thick alternating with red and green argillaceous dolostone and dolomitic shale, both of which contain mudcracks, scour- and fill-structures and cross-laminations; 2.5 m above base and in the uppermost metre are 10 cm thick layers of chert nodules and ?pebbles	6.5	56.4
8	LIMESTONE: fossiliferous and stromatolitic packstone to mudstone; burrowed, oncolites with *Teiichispira?* sp. cores (silicified), brachiopods, gastropods, nautiloids; masses of red chert; irregular upper surface	1.0	49.9
7	LIMESTONE AND ARGILLACEOUS DOLOSTONE: lime mudstone to wackestone containing small, conspicuous, partially dolomitized stromatolites in the lower part; an upper unit of limestone, green shale and red laminated dolostone containing pods of finely crystalline dolostone, the shale is conglomeratic with clasts of limestone and chert	2.4	48.9

UNIT NO	DESCRIPTION	UNIT THICKNESS IN M	CUMULATIVE THICKNESS IN M
6	DOLOSTONE: buff-weathering, finely crystalline, laminated to burrow-mottled; thin lime mudstone beds	4.8	46.5
5	DOLOLAMINITE AND LIMESTONE: interbedded on a 0.5- to 1-m scale, tan-weathering, microcrystalline, planar to occasionally cross-laminated and rippled dolostone with relic burrows, mudcracks and common chert nodules, and light-grey, lime mudstone with prolate LLH stromatolites and occasional mudcracks or medium-grey, burrowed, fossiliferous wackestone–packstone–grainstone; the most conspicuous fossils are gastropods and trilobites; a pronounced band of nodular chert occurs 4 m above base; some burrows are silicified	10.0	41.6
4	LIMESTONE, SHALE AND BRECCIA: lime mudstone to packstone and green shale that is dolomitic toward the top; along strike grades into a breccia of limestone fragments or rafts and chert clasts in a green shale matrix	1.3	31.6
3	DOLOLAMINITE AND LIMESTONE: tan-weathering, microcrystalline, parallel to crinkly laminated, locally burrowed and mud-cracked dolostone; lime mudstone to grainstone, burrowed, fossiliferous with local stromatolites, thrombolites, and hardgrounds; gastropods and cephalopods are particularly conspicuous in the limestones; at 2.5 m are ellipsoidal, brown-weathering dolomite pods overlain by 20 cm of red-weathering, argillaceous dolostone; this unit forms the first prominent ledge in the succession	7.3	30.4
2	DOLOLAMINITE AND ARGILLACEOUS DOLOSTONE: interbedded on a metre to centimetre scale, tan-weathering, microcrystalline, planar-laminated to minor cross-laminated dolostone with scattered bioturbation, mudcracks and stromatolites; red to green, variegated, finely laminated dolostones; several thin, light-grey, fenestral wackestone to bioturbated, fossiliferous packstone beds with conspicuous gastropods, cephalopods and stromatolites; nodular chert 3 m above the base	13.6	23.1
1	LIMESTONE, DOLOSTONE AND COVERED INTERVALS: tan-weathering, microcrystalline, finely planar to cross-laminated dolostone; light to medium grey, cryptalgal-laminated lime mudstone or oncolitic to bioclastic grainstones; two-thirds of this unit is covered	9.5	9.5